

SIR ISAAC NEWTON'S
PHILOSOPHY
EXPLAIN'D

For the Use of the Ladies.

IN SIX DIALOGUES
ON
LIGHT and COLOURS.

From the ITALIAN of Sig. *Algarotti*.

VOLUME II.

Quæ legat ipsa Lycoris. VIRG. EC. x.



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PHILOSOPHY

EXPLAINED

IN SIX DIALOGUES

BY

THE ITALIAN OF SIG. G. V. G.

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The FOURTH Dialogue.


Encomium on Experimental Philosophy, and an Exposition of the NEWTONIAN System of Optics.

THE next Day when we had disengaged ourselves from Poetry, which had at first given Birth to our Discourses on Light and Colour, and afterwards endeavoured to disturb and interrupt it, I began after the following Manner. It is now Time, Madam, to lead you into the most retired Sanctuary of Philosophy, from whence the Profane and those who are filled with Vortices, Globules, Atoms, subtile Matter, and like Imaginations are entirely excluded. This Philosophy which I am now conducting you to, is less pompous than that we have al-
B. ready

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ready discoursed on, but in Return, performs all its Promises; a Philosophy, which is contented with giving a History of Physics, and leaves to others the Province of making them the Subject of a Romance. You have had an Instance of the one in its Method of explaining the Nature of Vision, and the System of Vortices has given you an Example of the latter more pompous and splendid Philosophy, which boldly goes to the first Causes of Things, and laying down certain arbitrary Principles, upon these builds the World, and explains all the Phænomena of it according to its own Fancy.

As the Eye is now discovered to have an entire Resemblance to the artificial *Camera obscura*, all Philosophers will hereafter explain the Nature of Vision after the same Manner. But there will not be that Conformity in their Opinions concerning the Solidity of Bodies, Gravity, Light, and Colours, since the Cause of these Qualities can be known only by Conjecture. And how very hazardous a Thing this is, you have already
seen

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seen in the *Cartesian* System of Globules, to say nothing of *Mallebranche's* Reformation, which, notwithstanding all the Applauses at first given it, is now exploded, and shares the same Fate as the Globules. And this you may believe has been the Case with all the general Systems that have hitherto appeared, concerning the Causes of Things. They resemble vast Empires, which totter and fall by their own Weight and Greatness. I find then, said the Marchioness, that the *wherefore*, which so greatly excites our Curiosity, will be for ever hid from us, and the Pleasure of conjecturing, which is generally so adapted to the Taste of *Men*, will have no Charms for *Philosophers*. This really is a Circumstance, which will make the Condition of those Gentlemen not greatly to be envied by the Vulgar.

Conjecture (answer'd I) according to the Assertion of one of the most ingenious Authors in the World, is not to be allowed in any Thing but Geometry. In this Science, if the Certainty of

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Principles does not directly guide us to what we seek, it never leads us however to any Thing contrary, and always rewards our Searches with something equivalent. But what Uncertainty and Inconstancy is there in Natural Philosophy? Some affirm that there is a Vacuum, or Space void of all Body, and others will have every Thing to be Body. This Diversity of Opinions, with regard to Principles, must unavoidably produce very great and innumerable Disputes as they advance further, which extend so far as the fixing the Essence or Nature of Body, a Thing which one would imagine should of all others be the most certain in Physics, since Body and the Properties which depend on its Essence, are the perpetual Subject of Philosophical Inquiries. I cannot help comparing these Philosophers to those Critical Writers who correct some corrupted and defective Passage of an ancient Author. One of these Gentlemen gives one Reading, a second another, each supported with the finest and

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and most elaborate Arguments, and the Encomiums of the Journalists of the Learned. Some old Manuscript of the Author himself at length appears drawn out from the Dust and Obscurity of a Library, and then all the fine Readings of these profound Critics, and the Time they spent in inventing them, are sent into the Regions of *Ariosto's* Moon, and are there treasured up among other lost Things. Observations and Experiments are the authentic and original Manuscripts of Nature; and these, by overthrowing so many fine Systems, instruct us every Day, to be more cautious in puzzling ourselves to form Hypotheses. I look upon this Advice as a very great Benefit to Mankind, since it exempts them from no small Trouble and Fatigue. But the Misfortune is, that Men persist in a Refusal of this friendly Admonition, and are obstinately bent to spend their Time to no Purpose.

This is indeed a Practice that redounds greatly to the Honour of these Observations of yours (said the Marchioness.)

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chioness.) A System need only be ingenious, simple and elegant, to give them a Right to declare open War against it, they may be termed the *Erostratuses* of Natural Philosophy, which found their Glory in the Destruction of all that is grand and splendid. I must confess that I cannot be pleased with so malicious a Character. To what a Height would your Displeasure rise, answered I, if I had told you all that these Observations are capable of effecting. There is perhaps no System better grounded than this, that Animals have Wings given them in order to fly, and Legs to walk. And yet Observation has discovered to us certain Insects who have large Wings without ever making Use of them to fly with; and in the same Manner, there is one Animal, which, notwithstanding it has Legs disposed like those of others, formed in the same Manner and of the like Proportions, yet almost always walks upon its Back with its Legs upwards, just as if the first were not sensible they had Wings, nor the last,

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last, Legs. It is true, however, that if Observations had done no greater Service to the World than to destroy, we should not be much indebted to them. But by overthrowing perplexed and useless, and sometimes very troublesome Systems, how many good and useful Discoveries have these Observations furnished us with, in the Room of those Hypotheses they have overthrown?

Some melancholy Philosophers have imagined the Rays of the Moon were cold and humid, and therefore greatly to be feared, since there must be expected very dangerous Effects from their Influence. And in fact you see many Persons, even now, who believing the Effects of this Planet from the Tradition of their Fore-fathers, retire as soon as ever the Moon begins to rise, and (as they express it) gets Strength; and vast Numbers of People are perswaded that they have the Head-ach, if by walking in the Evening they have unhappily been obliged to receive the Infection of its Light.

The Experiments which have been

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made upon this, give us full Liberty to walk at what Hour we please, without apprehending any Danger from that Quarter. The Rays of this Planet collected in the Focus of a burning Glass or a Lens, do not cause any sensible Effect in the Bodies upon which they fall, notwithstanding they are sometimes two thousand Times denser when thus collected, than they ordinarily are. A Thermometre, which is an Instrument containing a Liquor that contracts with the least Cold, and dilates with the least Heat, does not suffer any Alteration in the Focus of these Glasses when they are exposed to the Rays of the Moon; whereas if they are exposed to those of the Sun, the Vehemence of their Heat surpasses that of the hottest Furnaces, so that the *Amiantus* which defended the precious Ashes of Antiquity from the devouring Flames of the funeral Pile, cannot defend itself from the violent Heat of these Glasses. The Rays of the Moon do not appear to have any other Quality than that of supplying the Absence of the Sun, and
inspi-

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inspiring a soft and pleasing Melancholy in the Hearts of Lovers.

These Sorts of Observations, said the Marchioness, I have no Objection to, which let the fine Systems alone, and deliver Mankind from ill-grounded Fears. To this Spirit of Observation, answered I, we are indebted for our Deliverance from other much more important Fears, Comets, Pillars of Fire, Showers of Blood, and *Ignes fatui*, anciently Marks of Divine Wrath, do not at present disturb so much as one half Hour's Sleep, except it be in those Persons who will always be the *Vulgar*, and always of a Temper fitted to receive these Impressions of Terror from others.

But how much are we indebted to the Study of Experiments! Astronomy, Natural History, and Anatomy, seem by the Assistance of this to be rather new Sciences born among the Moderns, than transmitted from the Ancients to us. To this Anatomy owes the Circulation of the Blood, and all the animal OEconomy, whose very Simplicity was
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the Cause of its being so little known among the Ancients. To this, Chemistry is obliged for its Phosphorus: Astronomy, for its exact Predictions: Hydrostatics, for an easy Method of Living, and carrying fresh Air for Respiration, in an Element denied to Men: for Acoustics, and their speaking Trumpet; their Projects, for rendering the Perfection of Hearing equal to that of Sight, and innumerable musical Instruments, the Offspring of Harmony. To this, Optics owe their Telescopes, Microscopes, Magic Lanthorns, and an infinite Number of other Wonders that perfect or flatter the Sense of Seeing.

Superstition, Credulity, and a greater Love for the Marvellous, than Truth, Negligence, and a Want of proper Means for Observation, have for a long time been insuperable Obstacles to Knowledge. How great a Treasure of Wonders has Natural History, after having rejected the Absurdities of the Ancients, demonstrated to us! New Modes of Production, Breathing, Seeing and Living, new Conformation of Parts,
new

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new Societies, new Modes of Being, unheard and unknown to past Ages.

The Reason of Mankind has been polished in Proportion as that of Brutes has been more considered; and the Arts themselves have been brought to Perfection by Observation upon certain Animals, commonly regarded either with Horror, or as the Refuse of Nature. Spiders have furnished our Manufactures with new Species of Silks; and the Eggs of a Fish, tho' yet unknown, may, with a little Apparatus, give us a fine purple Colour not inferior to that so much celebrated by the Ancients. Shall I inform you of the Experiments made concerning the Weight of Air, and the Power it has of dilating itself when compressed; Experiments once termed the Wonders of *Magdebourg*? Shall I give you an Account of the Equilibrium of Fluids, the Vegetation and Culture of Plants, which have afforded so great an Advantage and Ornament to Society? By these Experiments your Garden is embellished with the playing and agreeable Murmur of
arti-

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artificial Fountains; and these supply the Northern Tables in great Plenty with those delicious Fruits that Nature had confined to a warmer Hemisphere. The Orange by these transported from the *China* to the *Portuguese* Soil, sweetly allays the burning Heat of the Summer; and these Experiments have extracted from the Vines of the *Rhine* transplanted upon the burning Rocks of *Canary*, that agreeable Juice so pleasing to the Taste of Ladies. Still better and better, said the Marchioness. Is not this the Cluster of the promised Land by which you hope to allure me? and as we are in the Country, would intice me by the Hopes and Advantages which accrue from Observation to Agriculture and OEconomy? Without Dispute you have those ancient Consuls in your Head, who from the Triumph returned to the Culture of their Farms.

If I had a Design of inticing you, answered I, Madam, I should rather entertain you with talking of the polite Arts of which you are so fond, and which owe both their Original and Progress to
 Obser-

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Observation and Imitation. Gratitude requires you to think yourself obliged to these for the Pleasure you receive from the fine Lineaments and elegant Air of Countenance in the Medusa of *Strozzi*, the just Gradation of the Anger of *Achilles*, the Variety and Strength of Passions in *Cassandra*, that Master-piece of the *Timotheus* of our Age, the majestic Solidity of the Portico of the Rotunda, the elegant Strokes of *Guido*, and the magic Colouring of *Rubens*. What Riches has this industrious Philosophy brought into the Treasuries of Painting, by the Observation of so many new Animals and Plants? What an additional Beauty has it given by the Imitation of the Eastern Varnish, to certain Works designed for the Use of those People to whom Superfluity is necessary? What a fruitful Source of Similies and Descriptions has it by its new Discoveries opened to Poetry? The Sun, Stars, Shepherds, the *Hyrceanian* Tiger, and the like common place Comparisons, are delivered from the Weight which they alone

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alone have long borne in Poems, and we from the Fatigue of hearing them so often repeated. How great a Progress has the Elegance of Dress, which so greatly heightens the Beauties of Nature; and in short, the most polite of all the Arts made in our Age, by the Assistance of a curious Observation made upon pleasing Objects, Beauty itself, the most valuable Treasure with which Nature can enrich and adorn Youth, would often be a vain and useless Gift, if Observation had not consulted its Safety, by bringing in the strange, yet salutary Art of furnishing ourselves with a particular Distemper whenever we please? How many fair *Circassians*, who formed for the Pleasure of the Universe, are confined to a Seraglio, and subjected to the Caprices of one single Tyrant, and how many Beauties in *England*, the Mistresses of free born Hearts, owe their Empires and their Arms to an early Inoculation of the Small Pox?

But not to insist on what you may possibly think I might acquire too great an

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an Advantage from, nor to say any Thing further of Natural Philosophy, which seems a Province the most adapted to the Discoveries of Observations, is not Policy indebted to *these* for that wise and real Government, which renders the Southern Suns less pleasing than the Cloudy Regions of the North, where the Liberty of the People is made compatible with the Superiority of the Nobles, and the Authority of the Sovereign? Metaphysics, that Labyrinth of Reason, are obliged to *these* for a certain System of the Origin and Progress of our Ideas, and we for the Knowledge of our selves. The Chaos of Chronology and History has from *these* Observations received its Light and Order. Sir *Isaac Newton*, that divine Philosopher, who may be regarded as the Founder of human Knowledge, has from Observations drawn chiefly from the ordinary Course of Nature, ranged historical Facts in a certain Series, by joining Epochas, which the Ignorance or Pride of Mankind had set at a great Distance from

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from each other, in the same Manner as a judicious Observation had united the Boundaries of the Earth in Geography.

Conducted by this infallible Guide he, according to the Expression of one of his Countrymen,

Display'd the lucid Robe of Day,

and thence extracted the true Properties of Light and Colours (which had till that Time lain concealed and involved) without forming, like *Des Cartes* and his Followers, any imaginary System to explain the Nature of them.

This is a World entirely new, enriched with the most shining Truths, and discover'd by *Newton* alone, for there are not the least Traces of any Philosopher who ever appear'd there before him. His Treatise of Optics, the Production of thirty Years Study and Search, is an excellent Model of true Philosophy. One single Experiment of his has advanced our Discoveries more than all the ingenious and magnificent
Syl-

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Systems put together, that had ever gone before him.

An antique Column of the most worthless Stone has more Beauties in the Eyes of a Connoisseur, and will conduce more to the Perfection of Architecture than all the Galleries of Emerald and Adamant, invented by the Poets to adorn their enchanted Palaces.

But your Connoisseur, said the Marchioness, cannot admire or taste the Beauties of a Column, however antique, and well-proportion'd it may be, unless he first knows what a Column is. And how is it possible that we should understand the Properties of Light and Colour, as you tell me *Newton* does, without first fixing what the Colours themselves are, and explaining the Nature of them? *Des Cartes*, whose System you Moderns explode, tells me, that if a Ray of Light meets with the solid Parts of a Body, it is repelled and reflected, and I understand this very well, because he had before told me that a Ray of Light is nothing but a *String* of little Globules. But how can I ever understand
the

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the new Discoveries concerning the Qualities of Light, unless I am first informed what Light itself is?

Is there any Thing, answered I, more inexplicable than the Nature and Causes of muscular Motion? All the Differtations of Philosophers upon it have been in vain. (And indeed the more these dispute upon the Causes of Things, the more inexplicable do they generally make them.) And yet an excellent Painter, a *Michael Angelo*, by laying down certain Rules drawn from repeated Observations, would have informed you, that when the Body makes such a particular Motion or Effort, certain Muscles must be elevated, and others lowered and depressed. So that there is no Posture so strange but he could have foretold the various and almost infinite Motions they would produce. The famous Piece of the last Judgment, in the Vatican, is an evident Proof of his Knowledge in this Point.

The Loadstone is a Secret of the same Kind. Its Nature and the Cause of

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of its surprizing Effects are, and perhaps always will be as entirely lost to Philosophers as the *Punic* Language is to Critics.

Our Ignorance of its Cause, however, does not hinder us from making very many Discoveries of its Qualities. We know, for Instance, that if it be armed with Steel it can attract a much greater Quantity of Iron than it can unarmed. We have discover'd that on one Side it attracts another Loadstone, and repels it on the other, and constantly directs itself to the Poles of the World. To this, Natural Philosophy owes the Discovery of a great Number of Truths, to this Navigation its Compass, and Commerce and Mankind very many Advantages.

If it is ever possible to arrive at a Knowledge of the Nature of Things, this is the only Method, by observing and investigating, with the greatest Attention, their most secret and hidden Properties, their primitive and elementary Qualities, on which all the rest depend.

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Hitherto you have seen only the different Modes of the human Imagination in those Systems, continually changing and succeeding each other, to gratify the Pride of Man, that always deluded yet still credulous Being. But at present Light and Truth itself address you in the Language of Sir *Izaak Newton*. Let us hearken to it attentively, said the Marchioness. Let it dissipate any Remains of Darkness, that may still obscure my Mind, and conduct me into this new World of Philosophy.

I observ'd to you the other Day, answer'd I, that every Ray of Light, however slender, is nothing but a Collection of innumerable other Rays, which are not all of the same Colour, notwithstanding the whole Ray appears white: But some of these Rays are red, orange, others yellow, green, blue, indigo, or violet, besides innumerable Degrees of intermediate Colours between each of these seven principal Ones. These Rays of different Colours, which are called *primary*

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many or *homogeneous*, blended together form a heterogeneous Compound Ray of a white or golden Colour, such as a Ray of the Sun appears, just in the same Manner as different Colours mix'd together upon a Painter's Pallet, compose a new One, which has something of all the others in general, but is different from each of them in particular. These are the Reasons why that Poet (whom you discovered rather from his Esteem for you than by his Stile) in speaking of Light, uses the Expression *golden* and *sevenfold*, an Epithet anciently appropriated to the Nile and the Shields of Heroes. This *sevenfold* Light is the inexhaustible Treasury of those innumerable Colours, which form the gay Picture of the Universe, and its Rays are not tinged with the Purple or Sapphire, either when they are refracted through a Prism, or reflected from a Surface, but derive their Colour from the Sun himself with that Heat and Lustre, which they receive from him, tho' not discovered by Vulgar Eyes.

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In short, every Ray may be consider'd as a Fibre composed of innumerable other Fibres or Filaments, each of which has a peculiar, proper, and unchangeable Colour, which it would infallibly discover to our Eyes, if it could be seen, separated from the other Colours, which concur with it in forming the white or yellowish Colour of Light. But how indefatigable must be the Industry of that Philosopher, who could divide and resolve the whole Ray into its primary and elementary Rays, so that every one of them should exhibit its own Colour? It is certain this Division could never happen if these primary and homogeneal Rays were not of such a Nature that some are refracted more than others in passing all with the same Inclination out of one Medium into another, (from Air into Glass, for Example) and by this Means are disunited and separated from each other.

This Proposition, that *Rays which differ in Colour differ also in Degrees of Refrangibility*, is the fundamental
Disco-

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Discovery, upon which the *Newtonian* System of Optics is built. Agreeably to this it is demonstrated that the violet Rays are the most refrangible of all. Next follow the indigo, then the blue, green, yellow, orange, and lastly the red, which are the least broken of any by Refraction. Do I explain myself clearly enough, *Madam*, for you to conceive my Meaning?

Extremely well, answered she: I understand very easily, that Nature, by making Rays which are different in Colour, different likewise in Refrangibility, has furnished Philosophers with a Means of separating them, which otherwise would be impossible. The Properties of this Light which you have been describing, are indeed very surprizing. A Philosopher must have a very great and enterprizing Genius that could make such Discoveries; and his Credit ought to be supported by very weighty Arguments drawn from frequent Observations, which I must confess I am extremely impatient to be acquainted with. I who was at first a

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Cartesian, afterwards a Disciple of *Malbranche*, now find myself without any System at all. This is a Vacuum that does not greatly please me, therefore I am in Haste for it to be replenished with other Observations.

These will very soon amply repair the Losses you have sustained by them, answered I. It would be well if every thing else in the World that does us an Injury, would make as good a Compensation for it.

Imagine yourself to be in a Place of *Milton's* visible Darkness, or rather still darker a Place, if you will be absolutely deprived of all Light; and this shall be our Theatre of Reasoning and Observations.

Let a Ray of the Sun enter in at a Hole made in the Window-Shutter, and let a Glass Prism be placed horizontally at this Hole, to refract the Ray in such a Manner as to throw it upon a Wall opposite to the Window, so that as it is going out of the Prism, it is almost horizontal and parallel to the Pavement of the Chamber; whereas if it
had

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had not been refracted, but direct, it would fall upon the Pavement itself, and there form a white Image of the Sun of a Figure almost round. That Spectrum, or Image of the Sun, which the refracted Ray forms upon the Wall, is very different from that which the direct Ray formed upon the Pavement; for as the Image of the direct Ray was almost round and entirely white, that of the refracted Ray is of a Figure nearly resembling a Fish at Cards, and varied with an infinite Number of Colours, among which the seven primary ones are distinguished and placed in a shining Order, one after another.

*The jolly Peacock spreads not half so fair
The eyed Feathers of his pompous Train;
Nor golden IRIS so bends in the Air,
Her twenty-colour'd Bow through Clouds
of Rain,)* FAIRFAX.

I am very glad to find that *Tasso*, said the Marchioness, who had before a little transgressed against the Laws of Refraction for the sake of his *Armida*, has amended his Fault, and is at present reconciled to Optics.

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These Colours, answered I, with which the Image is painted, are disposed in such a Manner, that the red is in its lower Extremity; above this is placed the orange, afterwards the yellow, then the green and blue indigo, and lastly the violet, which is placed in the upper Part of the Image. Innumerable Degrees of intermediate Colours insensibly connect and unite the seven primary ones. Neither *Correggio*, *Titian*, nor his Rival *Rosalba* did ever unite and shade their Mezzo Tinto's with so much Exactness to form the Oval of a Face.

In order to explain this great Change, we must suppose one of these two Cases, either that Light is composed of Rays differently coloured and differently refrangible, so that the Prism does nothing but separate them from each other when they are transmitted through it; and by this means the different Colours are formed, and the Image which would otherwise be round, is of an oblong Figure. This is one manner of explaining this Phenomenon. The other is, that the Light in passing through

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through a Prism, acquires Colours which it had not before, and moreover, that every Ray is shattered, dilated, and split into many other diverging Rays painted of a different Colour; and this is the Reason why the Image is coloured, and of an oblong Figure.

This last is the Supposition of *Grimaldo*, a Philosopher, who preceded Sir *Isaac Newton*; and this System is called the *Dispersion* of Light. You see it is necessary, unless we admit the different Refrangibility, to suppose this Dispersion, in order to explain why the coloured Image of the Sun should have a Length much greater than its Breadth, after being refracted by the Prism.

This Experiment, said the Marchioness, which has cost me so much Attention to understand, and this Oblongitude of the solar Image, are not sufficient to prove the different Refrangibility, because all this Phænomenon may be as well explained by *Grimaldo's* Dispersion of the Light, which is a System very different from Sir *Isaac Newton's*. I want to see some Experiment, which

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cannot possibly be explained by any other System than the *Newtonian*, and that I believe would satisfy me. This, answered I, is the very thing necessary to prove not only the different Refrangibility, but every other Principle in Philosophy; and this Sir *Isaac Newton* has done (without knowing, perhaps, that it would one Day give Pleasure to a fine Lady) whatever a certain Author may say to the contrary, who accuses him with having drawn more Consequences from his Observations than he ought to have done, one of the greatest Faults that a Mathematician can be charged with. This Author reproaches Sir *Isaac* with having inferred the different Refrangibility of the solar Rays from the preceeding Observations; whereas Sir *Isaac* declares in express Terms, that the Observation is not sufficient for that Purpose, because this strange Appearance of the Image may proceed from the Shattering of the Rays, as *Grimaldo* supposes; or from an Inequality of Refractions, not constant, but only casual, and therefore can have nothing deduced from

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from it. The more scrupulous this great Philosopher appears in his Reasons, the more licentious does his Adversary seem in his Accusation. In order to remove the Dispersion of *Grimaldo*, and the fortuitous Inequality of the Refractions, he invented the following Experiment, which is as it were the Arbitrator and Judge of the Controversy.

He received the coloured Image formed by the Prism, and cast upon the Wall, upon the Face of another Prism placed upright, in such a Manner, that the red of the Image should fall upon the lower, and the violet in the superior Part of this Face, and the other intermediate Colours should fall respectively in the intermediate Spaces betwixt the red and the violet.

If the first Prism, which was placed horizontally, refracted the Rays upwards, this second, placed upright, must refract them sideways, either on the right or the left; so that if they were at first thrown almost directly upon the Wall opposite to the Window, they must now strike it obliquely, and

with some Inclination. The Refraction then which the Colours are to suffer in passing sideways thro' this second upright Prism, is the Thing which must determine the Question, either in Favour of Sir *Isaac Newton's* Supposition of the different Refrangibility, or for *Grimaldo's* Notion of the Shattering of the Rays, or lastly, must give the Preference to a fortuitous and casual Inequality of the Refractions, which cannot agree with any System at all. For, if the solar Image, formed by the first Prism which refracted the Rays upwards, received its Colours and oblong Figure from a Dispersion or Dilatation of every incident Ray, a second transverse and sideways Refraction caused by the second Prism, must after the same manner shatter and dilate the Rays of this Image sideways, and render it of the same Oblongitude in Breadth as it had before been in Length; so that a new Image would be painted upon the Wall of the Chamber which is behind the second Prism; and this Image would be coloured differently from what it was

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was before, and be changed from an oblong Figure, to one almost square.

Lastly, if the Colours and oblong Figure of the Image formed by the first Prism, were occasioned by a fortuitous and accidental Inequality of Refractions, who can tell what Variations Chance might have produced in the Combination of the second Prism, and in the new Refraction which that Prism gave to the Light?

But whatever Effect Chance might produce in this Case, it is certain it could never agree with what the *Newtonian* System aims at. According to this System, if the colouring and oblong Figure of the Image formed by the first Prism, were occasioned by the Separation of Rays differently coloured and differently refrangible, a second Refraction made sideways can only incline this Image, and must leave it just the same as it was before with regard to its Colours and oblong Figure.

How will it *incline* the Image, said the Marchioness? I do not understand the Reason of this. You will soon

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understand it, answered I, when you reflect, that if the second Prism was removed, the Rays would all strike the Wall almost in a direct Line. Now if the second Prism refracts the violet Rays, that is, turns them sideways and transversely out of their Path, more than it does the red, those must strike the Wall more obliquely than these, or in other Words, the violet must fall at a greater Distance from the Prism than the red. The intermediate Colours too, between the red and the violet, will fall upon intermediate Places of the Wall: Thus the Image will appear inclined, and as it were leaning with its violet Extremity farther from the Prism than the red is. These Effects must happen according to Sir *Isaac Newton's* System; and these in reality do happen, as I myself have often had the Pleasure of seeing.

If after the second Prism there be placed a third and fourth, in order that the Image may be successively refracted sideways through them all. Those Rays which were refracted more
than

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than the rest in the first Prism, will be more refracted too in the following Prisms. But the Image will not be dilated sideways, nor coloured differently from what it was at first.

Nature, said the Marchioness, has pronounced the grand Judgment, and of three Systems that contended for it, the *Newtonian* has carried the golden Apple. I must confess this Decision does not displease me; for to say nothing of the accidental Inequality of Refractions which does not deserve the Prize, *Grimaldo's* Supposition of the Shattering and Dilatation of every particular Ray, had something too perplexed and imbarassing in it. If you think the Judgment which Nature has pronounc'd in favour of our Philosopher, answer'd I, to be so just, that of his Adversary, whom I lately mentioned, will appear extremely capricious, who asserts, that Sir *Isaac Newton* has, by agreeable Experiments, confirmed the Observations of *Grimaldo*. I am not so greatly surprized at this Adversary, replied the Marchioness, who does not appear to have

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have any great Knowledge of the Matter, as at *Grimaldo* himself, who neglected to prove the Truth of his Dispersion of the Rays, by so easy and simple a Experiment as this, which requires nothing more than a second Prism after the first. One would imagine that it should have been very obvious to a Person bent upon making a System. Say rather, answered I, to a Person long exercised in the Arts of Observation, for a Love of building Systems and making Experiments, are two Things that seldom go together. But it generally happens that the most simple Things are the most difficult, and consequently the longest before they are found out. The Circulation of the Blood, for Example, appears to be a very easy Discovery, and one would imagine should have been very anciently made. When an Orifice is opened in the Arm the Arteries swell from the Heart towards the Extremities of the Body, and the Veins, on the contrary, from the Extremities of the Body towards the Heart. This evidently shews that certain Vessels, that is, the Arteries,

are

are designed to convey the Blood from the Heart to the extreme Parts, and other Vessels, namely the Veins, to carry it from the Extremities to the Heart. Besides, the Death of *Seneca* might have furnished the Ancients with a physical Experiment as well as a moral Precept. It was impossible that all the Blood should be emitted through the opening of the Veins, unless those of the superior Parts had a Communication with those of the inferior; or in other Words, unless it circulated through the whole Body. It appears then that it was much easier for the Ancients to discover the Circulation of the Blood, who had so many Experiments ready prepared to their Hands, than for *Grimaldo* to find the Falshood of his Dispersion, because his Experiments must have been the Effect of his own Labour and Invention.

It is true, some Bigots for Antiquity pretend to find this Discovery in *Hippocrates*, so that according to them, all the Inventions of the Moderns, and all our Distempers were known to the Ancients.

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cients. But this Notion is the same as if a *Vellutellus*, or some other zealous Admirer of *Petrarch* should discover the *Newtonian* System of Optics in these Verses,

*While the great Author of his Frame expires,
The conscious Sun withdraws his active
Fires;
Pale sickly Shades o'rspread his languid
Ray,
And ev'ry beauteous Colour fades away.*

The most simple Things are generally discovered the latest, and with the greatest Difficulty. This Aphorism, said the Marchioness, is too well verified even in the Toilet, where an elegant, but simple Disposition of our Hair or our Patches, often costs great Trouble, and the utmost Anxiety of Mind.

According to this Principle, answered I, Sir *Isaac Newton's* Experiments must have cost him an infinite deal of Labour. For if the preceding Experiment,

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ment, to prove the different Refrangibility of the Rays, is at once simple, agreeable, and conclusive, all the others which he invented for the same Purpose are no less perfect, and yet appear so very obvious, that every one would imagine he himself might have as easily found out.

How, said the Marchioness, is not this Experiment sufficient to prove the different Refrangibility without seeking for any more? Have I acted wrong in suffering myself to be too easily convinced? No, Madam, answered I, a Lady cannot err in this Point. But Sir *Isaac Newton* himself does not desire you should assent to his System so soon. This Experiment, without Dispute, is sufficient to demonstrate the different Refrangibility, but not to satisfy a Philosopher resolved to try Nature a thousand Ways, and put her to a thousand Proofs, in order to establish his Belief on a sure Foundation. You seem, said the Marchioness, to represent Nature as a Coquet, and Sir *Isaac Newton* as a jealous Lover, who never thinks he has
Proof

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Proof enough of the Fidelity of his Mistress. This, however, answered I, was the only Object of his Love. I am very sorry that I cannot shew you all the Experiments which he invented for this Purpose, in order to present you with the most finished and beautiful Piece that philosophical Jealousy ever composed. But the Parts I shall shew you will assist you to form an Idea of the whole, just as the Obelisks and Amphitheatres discover the Grandeur of ancient *Rome*. Let me intreat you, said the Marchioness, to make me a compleat *Newtonian*. I plainly see that by my Conversion I shall acquire the Knowledge of Truth without losing that Pleasure which I found in being deceived.

In the dark Chamber which we have prepared for our Experiment, continued I, let a white Thread be extended horizontally against the Window, but at some little Distance from it. Let two Rays of the Sun enter at two Holes made in the Window-Shutter, which refracted by the two Prisms, may paint
two

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two coloured Images upon the opposite Wall. When this is done, we must recommend ourselves to the Genius which presides over Optics, and then patiently wait till the Half of this Thread be illuminated by the red Rays of one Image, and Half of it by the violet Rays of the other. Let the Wall opposite to the Window be covered with a black Cloth, that the Colours which would otherways be reflected by the Wall, may not disturb the Experiment; for at present we want no other Colours but those of the Thread, which must be alone distinguished. This Thread must be observed through a Prism placed before the Eyes in such a Position, that all the Objects seen through it appear higher than they really are. The Thread too will appear to be transported higher by the Refraction; but because the violet Half should suffer a greater Refraction than the red, it will be much more transposed than the red, so that the Thread will appear divided into two Parts, the one illuminated with violet, the other with red,
and

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and the red will appear lower than the violet.

This Experiment, if we should exclude every other, is intirely agreeable in all its Parts to the *Newtonian* System. If the violet Part of the Thread be illuminated with indigo, the Thread will appear less divided than at first, the indigo Half approaching nearer to the red than the violet did, which must necessarily happen, because the Difference of Refrangibility between the indigo Rays and the red, is less than that between the red and the violet.

If from Indigo this Half be illuminated with blue, the other Half still remaining red, the Thread will for the same Reason as I before mentioned, appear less divided than at first, and still successively less if it be illuminated with the other Colours in order, green, yellow, and orange, till at length becoming red like the other Half, the Thread will no longer appear broken nor divided in two as at first, but whole and continued, because now the Colours of each
Half

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Half have no Difference in their Refrangibility.

A like Experiment may be made with a Paper, the one Half coloured with red, and the other blue; placed afterwards upon a black Cloth, and looked at through a Prism, it will appear broken and divided into two Parts. A Paper illuminated with four Colours, (which I have myself seen demonstrated) that is red, yellow, green and blue, ranged one after another in the order I have named them, appeared through a Prism divided into four Pieces, like the Steps of a Ladder. The blue is sometimes the highest of all, and sometimes lowest, as the Position of the Prism requires. This Experiment varied in as many Ways as the fruitful Imagination of *Paul Veronese* would vary the Subject of a Picture, always succeeded so well, as to have greatly confirmed this System, if its Author had suffered it to need any Confirmation.

I must ingenuously confess, said the Marchioness, that tho' I have always regarded the Mathematicians with a singular

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gular Veneration, I do not yet understand what their Demonstrations are. However familiar they may at present be rendered, I do not comprehend them enough to find the Solution of a Problem among the Patch-Boxes and Perfumes on my Toilette. I now begin to fear that my Ignorance of the Deity I worshipped greatly increased my Veneration for it. Their Evidence causes so great a Noise in the World, that I was perswaded every thing else, however well it might be proved, had only a small Degree of Probability when compared with these. At present, I cannot conceive it possible for any mathematical Demonstration to be more certain than Sir *Isaac Newton's* different Refrangibility, and yet this is a thing merely physical. But you are to consider, Madam, that the Person who has treated upon this physical Subject, was the greatest Mathematician that ever appeared in the World. We may affirm then, replied the Marchioness, that as every thing which *Midas* touched was transformed to Gold, so every thing that

that Sir *Isaac Newton* handled became Demonstration.

If ever Physics could hope to vye in Certainty with Geometry, answered I, they might with some reason expect it when treated by Sir *Isaac Newton*, tho' there is a very great Difference in the Nature of their Proofs.

Physics can only consider a vast Number of Particulars, make Observations upon them, and thence deduce general Propositions, whereas Geometry by a more expeditious and certain Way, abstracts particular Cases, and founds its Demonstrations upon Nature; and the Idea of the Thing itself, whereon it treats.

All that a Mathematician demonstrates to you concerning one Triangle, will be true in all, be they of what Species they will, because he considers nothing but what is necessarily included in the Nature of a Figure terminated by three right Lines; and as this is found in all Triangles that can possibly be either made or imagined, his Proposition will hold true in all.

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On the other Hand, a Naturalist will tell you, that all Bodies here below gravitate, and if left to themselves descend; but he does not, like the Mathematician, deduce this Proposition from the Nature of Body, (for that is unknown to him) but from a daily Observation that Gold, Silver, Gems, Water, Air, and a thousand other Bodies gravitate, and do it constantly by Day and Night, in Summer and Winter, fair and cloudy Weather; from whence it may reasonably be inferred by Induction, that every other Body gravitates at all Times, and in all Places.

But however reasonable this Method may seem, so great a demand for Proofs implies a Want of Demonstration, just as a too great Attention to Dress, argues some Defect of natural Beauty in a Face. Who can tell, but notwithstanding such a Multiplicity of Observations, some may question whether there be not a certain Body with which we are yet unacquainted, that has no Gravitation? Or if there be not some Country in the unknown Tracts of the southern Pole, where Bodies have
not

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not that Quality of Gravitation which we discover them to be indued with in all the known World? Or lastly, whether in past Ages there may not have existed a certain Body that did not gravitate? You will grant, however, said the Marchioness, that where the Number of Observations is so great as that from whence the Gravitation of Bodies, and the different Refrangibility of the Rays of Light are deduced, that Person must be inexcusable who doubts their Evidence, unless it was prescribed him by a Physician for his Health.

If there are some, answered I, too excessive in their Doubts, there are many others too bold in their Assertions. All do not imitate the prudent and necessary Reserve of our judicious Philosopher: Some are contented with one single particular Case, from which they hastily deduce a general Conclusion, like those who form a Judgment of the Temper and general Character of a whole Nation from the particular Humour of a single Person, whom they have seen perhaps once or twice at a Coffee-House.

Sir

Sir *Isaac Newton's* Antagonist whom I lately mentioned, imagining he had overthrown the System, and principally the different Refrangibility, in order to prove himself the Opponent of this great Author, even in the Method of philosophising, has put together a general System (hinted at by others, but not followed) formed upon particular Cases, which well examined, are nothing but Consequences of that which he imagined himself to have overthrown. He supposes certain Grounds, and a Mixture of Light and Shade; and the different Combinations of these are according to his Opinion, the Cause of different Colours — Can a Combination of Light and Shade, interrupted the Marchioness, ever produce red or yellow? A Phænomenon must be very unfortunate, whose Explication depends on this System. Perhaps, answered I, those Phænomena which contradict general Laws, those Monsters of Optics, if there are any such, are sent by Nature to this System for their Explication; and do not these fine Colours
of

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of yours to, deserve a little Punishment for all the Mischiefs they have caused? But see the unhappy Condition of the poor prismatic Colours, which certainly do not merit the Correction that yours do; and from hence you may form an Idea of the Value of this System.

It affirms, that when a Ray of the Sun is refracted by a Prism, these Colours are produced by means of two sorts of Images; the one formed by the Dispersion of the solar Rays, and the other by that of the Rays of Heaven, which are contiguous to those of the Sun. What, said the Marchioness, does this Philosopher attempt to bring this *Dispersion* again upon the Stage? Had he never seen the Experiment of the second upright Prism, which has for ever banished this Supposition from the Province of Optics?

Authors, answered I, have their Eyes formed differently from those of other Men. The Sun is light, and the Sky comparatively dark. This was sufficient to furnish the Philosopher we are speaking of, with Abundance of Rela-

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tions betwixt Light and Shade (the Veils, as he expresses it, formed by these two Images) from whence he draws an Explication of the Difference of Colours in a Prism. I fancy, said the Marchioness, this Explication will not be very simple; it appears to me sufficiently perplexed. Not to insist upon this and many other Difficulties which this System is chargeable with, we will confine ourselves to the following Objection, answered I.

If it be true that this Diversity of Colours depends on a Mixture of the Rays of these two Images of the Sun and Sky, and from their shadowing each other, it is certain that if there can be found a Method to prevent the celestial Rays from coming to the Prism, and consequently from being refracted and mixt with those of the Sun, the Colours will vanish with all that fine Theory which arises from the Mixture of those two sorts of Rays.

Now this may easily be effected, if before the Ray of the Sun (which enters at the Window of the dark Room)

be

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be refracted by the Prism, the Middle of the Ray be transmitted through another Hole made in a Table, or a Pastboard placed at some Distance from the Window: In this Case so far is the Prism from receiving the celestial Rays contiguous to those of the Sun, that it receives no Rays from the Sun himself, but what flow from his Disk, and is not at all affected by those which proceed from his Edge. It is evident then that if this System be true, the Colours of the Images in this Case could not appear, which is absolutely contrary to Experience, a Disgrace pretty familiar to this System.

You seem, said the Marchioness, to resemble *Bacchus* throwing down the Giants, who attempted to dethrone the Gods, in order to usurp their Places. The Spirit of Ambition appears no less Arrogant in this Author, than in those presumptuous Sons of Earth.

You are to suppose, answered I, that an Author is often as strongly desirous of giving his Name to a new System, as a *French* Lady can be of giving her's

to a new Fashion. How happy would they be, if, like that *Chinese* Emperor, who burnt all the Books of History preceding his Reign in order to make his Name the first Epocha of it, they could destroy all preceding Systems to make their own the Epocha of human Knowledge.

Besides, Sir *Isaac Newton's* System came from a Country too far beyond the *Alps*, to be favourably received among *Italians*. It would be very surprizing, if a System, produced in *England*, had not been treated with Aversion by some Persons in a Country so near the Sun as ours. I do not see, replied the Marchioness, why a System should meet with the worse Usage for being a Native of *England*. For my Part, as much an *Italian* as I am, I do not believe that I should be prejudiced against a well grounded one, even if it had been produced in *Ireland*, or *Nova Zembla*.

You are not to imagine yourself, answered I, to be ranked with the Generality of Mankind. A Sea, a River, or a Chain of Mountains placed between
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some People and a certain Truth, are insuperable Objections to their Reception of it. Perhaps as the *Romans* found a certain *Je ne sçais quoi*, in the Stile of *Livy*, which discovered the *Paduan*, so our *Italians* find a *Je ne sçais quoi*, in every Truth that comes from beyond the *Alps*, which does not agree with their Taste. These Gentlemen, said the Marchioness, must have a very distinguishing Judgment to discover such Differences as these, or it rather argues, they have no Taste for Truth, who find any thing foreign in the Proofs of a different Refrangibility. In this I may venture to affirm myself a better *Italian* than they, since the least Difference in this Case must turn to our Disadvantage.

You, Madam, said I, are a Citizen of the World, and your Senses formed for Truth are Proof against the Objections of those who only appear to be zealous for it. You will find a new Demonstration of the different Refrangibilities drawn from the Difference in the Focus of a Lens, through which the different Colours are viewed.

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The Image of the Letters of a Book, formed by a Convex Glass, illuminated by the red Rays of a Prism appears distinct at a certain Distance from the Glass: The Image of the same Letters, when illuminated by the blue Rays, is not distinct, but at a less Distance. In the like Manner, the four Colours, red, yellow, green, and blue, of the Paper we before mentioned, are not equally distinct when placed at an equal Distance from the Lens. The blue is nearest, next follows the green, afterwards the yellow, and last of all the red, whose Rays being less refrangible than the rest, must be collected and united at a greater Distance from the Lens.

Might not some wise Caviller, said the Marchioness smiling, gravely object, that the Book which first received the red, and afterwards the blue Rays, was wrote in *English*; and that in order to prove the different Refrangibility, it was necessary for it to be *Italian*? But after all, it is an infamous Thing to be so hardened against Truth. Are not these
Expe-

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Experiments sufficiently decisive? And can there in any Country of the World be assigned a Cause, why the Image of one Colour should be nearer to a Lens than that of another, unless it be the different Refraction which they suffer in passing through the Lens. Do not put yourself in a Passion, Madam, said I, the different Refrangibility will be true, notwithstanding these Objections. You may still safely believe it, as many other judicious Persons do, in Defiance of that obstinate War which the Antagonist of our Philosopher declared against it. The *Newtonian* System had the same Fortune as that Field where *Hannibal* encamped when he besieged *Rome*, which did not sell at all the worse upon that Account: Or rather, you may look upon these Objections as the satyrical Verses, those miserable Invectives which the Licentiousness and Malignity of the common Soldiers, mixt with the Acclamations and Glory of a *Roman* Triumph. The Beauty and Simplicity of this System did not deserve to pass unmolested by Envy and

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Censure, that Tax which Merit is bound to pay to the Public.

A celebrated Minister (*) at once capable of the sublimest Projects and the lowest Employments, and a whole College, joined their Forces against the Applauses paid to the *Cid*. For a like Reason *Moliere's Misanthrope* was recited to the same Audience that listened to the Sermons of *Cotin*. How often have the celebrated *Caracci* had the Mortification of seeing their fine Pieces sold in their Life-time by the *Ell*, (if I may use that Expression) which now are the Ornaments of the best chosen Galleries, and paid by the Admiration of Connoisseurs, better than by the Gold of the Rich!

It was necessary for the Honour of Sir *Isaac Newton's* System, that it should be attacked on all Sides, and that some should dispute the different Refrangibility of the Rays, while others wrangle about the *Immutability of Colours*, which is another of their Properties discovered by our penetrating Philosopher.

(*) Cardinal *Richelieu*.

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The Experiment upon which this new Quality of Colours is principally founded, was renewed in *France* by Monsieur *Mariotte*, a Man exceedingly well versed in the Arts of Observation. This Experiment in his Hands produced an Effect contrary to what Sir *Isaac Newton* had given Reason to hope for. Thus a System, the flow and considerate Offspring of Reasoning and Experience, was esteemed imaginary and vain; and a grave Philosopher, who spent his whole Life in the Study of Truth, passed for a Reveur, or an Impostor.

What is this you tell me, said the Marchioness, of an Experiment in *France* contrary to that of Sir *Isaac Newton*? Is it possible that two Men equally attentive and accustomed to Observation, should need a third to decide a Matter of Fact? It is not surprising that two People should reason differently upon the Circumstances of a Fact according to their different Principles, as in the Case of a Person who shifted his Linnen three times a Day, one asserted that he must be extremely neat,

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and the other that he was a very Sloven. But to dispute and mutually to deny the Fact itself, I always thought reserved for silly Women and Enthusiasts.

It is certainly, answered I, a great Reflection upon Philosophers, when we find them dissent in Matters like these; it at least demonstrates that one of them must have been inattentive in observing the Laws of Nature. Those rational Horses so far superior to us Men, which *Gulliver* discovered in the Island of the *Houyhnyms*, the last Place where he arrived at in his allegorical Voyages, were extremely surprized to find such Contradictions among our Philosophers, that is, those of our Species who take the most Pains to cultivate their Reason. These happy Animals know not the Meaning of Uncertainty and Doubt in Matters of Fact. The Dishonour that Philosophers receive upon this Account is very great even among us, and there are too many Examples of it.

Two famous Academics which have equally Truth for their End, and Emulation for their Companion and Guide, disputed

disputed upon a Fact, by which is demonstrated the Refraction which Light suffers in passing from a Vacuum into Air. That Academy which maintained the Refraction was at length victorious; and it was necessary that even this Truth should be contested in order to be admitted. Some from Experience will tell you, that in breathing, the Air passes from the Lungs to the Heart, while others alledge the same Experiment to prove that it does not. Many discover certain little Machines and Organizations in the Glands of a Body, which others affirm cannot be seen. Fancy and Prepossession have the same Influence here as in all other Things, and make us think we discover in Objects, without us, what runs strongest in our own Mind. Thus a few irregular Strokes will appear to the Eyes of a Painter the Contour of a Leg or a Face, Wind-mills become Giants to *Don Quixot*, and Fires and Beeches seem transformed to a fine Lady in the Eyes of a Lover.

An Observator must not search into
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Experiments in order to find his own Opinions there, like that Person who looked for his Pedigree in *Homer*, because both the one and the other will every where meer their own Imaginations. Natural Philosophy, like Poetry, requires a Man formed expressly for it, a *Malpighi*, a *Reanmur*, a *Boyle*, not moved by Authority, seduced by Fancy, nor terrified by Difficulties, a Man, (if we will believe a celebrated Writer) dexterous, active, and curious as the *French* and *English*, and reserved, cautions and circumspect as the *Italians* and *Spaniards*. Why not the Patience of some other Nation, said the Marchioness, instead of the Caution of ours, which is too like Diffidence to redound greatly to our Honour. This Author, answered I, considers only the good Qualities of different Nations. But you would be better pleased, perhaps, if the Part we contribute to the Formation of a perfect Philosopher, were the religious Attention of our passionate Lovers. I am acquainted with one of these,

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these, said the Marchioness, who would be a *Newtonian*, if Philosophy was his Mistress.

This Attention, answered I, might carry these Gentlemen to a great Height of Superstition; as it does a Naturalist, who prescribes it as a Rule of Art, whenever an Experiment is made, to mark exactly the Country, Hour of the Day in which it was effected, what Wind blew at that Time, the Degree of Heat, and Drought of the Air, with many other Circumstances of this Nature, which in some Cases may be proper, and even absolutely necessary, but in others I really do not see of what Service they are, for in looking upon a Paper of two Colours with a Prism, it is of no Sort of Importance whether the Wind blows East or West, whether the Time of the Year be Autumn or Spring, the seventh or twentieth Day of the Month. These circumstantial Naturalists resemble an Antiquarian, who should copy the Cornice of an Inscription with as much Exactness as the Inscription itself.

Physic,

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Phyfic, replied the Marchionefs, has almost divested itfelf of the Prejudice of obferving certain Seasons of the Moon, as a proper Time to apply its Medicines; and perhaps Natural Philofophy has affumed it in her Stead, that thefe fuperftitious Notions may not be destroyed, but there may always be pretty near an equal Dofe of them in the World.

It muft be confefled, however, answered I, that there may always be hoped fome good Effects from this diligent Difpofition, even tho' it be carried to fuch a Degree as to become ridiculous: But we can never expect any Good from Negligence. You will fee an evident Proof of this, in that celebrated Experiment of Sir *Ifaac Newton*, before which all the ancient Idols of Optics fall to the Ground; thofe imaginary Systems which fupposed Colour might be changed by Refraction, Reflection, the Continuity to Shadow; and in fhort, that Colour is nothing but a certain Modification, as they exprefs
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it, of Light, which may easily be changed by these Circumstances.

But Sir *Isaac Newton* has shewn the Falshood of this Opinion, and demonstratd that a Ray, for Example, red, well separated from all the rest, will constantly keep its Colour in Spite of any Refraction or Reflection it is made to suffer, or any other Method that the fruitful Invention of a Naturalist can contrive to torment it. The same Constancy will hold good in all the other Colours, if they are well separated. The grand Experiment which furnishes us with these agreeable and surprizing Truths, is this which follows.

The Image of the Sun formed by the Conjunction of a Prism and Lens is received upon a Paper; by this Conjunction the Colours are much more unmixed and better separated than they would otherways be.

Having thus made a more perfect Separation, the Rays of different Colours must pass successively through a Hole in the Paper, that they may be refracted

refracted by a second Prism, in order to prove whether this new Refraction can produce any new Colour. If it should, we must confess that Colour is nothing more than a certain Modification which the Light acquires in passing through the Prism; and then Philosophers may set their Imaginations to work, in order to find out what Notions, Figures, and the like, are necessary to produce this Modification.

But on the other Hand, if the Ray constantly preserves its own Colour without the least Alteration, we must agree that Refraction has no Share in the Production of Colours, and abandon the ancient System of Modification; and all its ingenious delusive Dreams will vanish at the rising Morn of the *Newtonian* Truth.

Now the Experiment we are upon, demonstrates that a homogeneous Ray, red, yellow, blue, or of any other primary Colour, is not in the least altered, by a new Refraction, nor even by a great Number of Refractions which it is successively made to suffer. It is not
changed

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changed either in its Colour or Degree of Refrangibility, which remains constantly the same. Thus if two Rays, one red, and the other violet, be made to fall one after another upon the second Prism, with the same Incidence (that is, if both the Rays coming from the same Point, fall likewise upon the same Point of the Prism.) If the Rays, I say, fall upon the second Prism in this manner, the violet after the second Refraction, will strike the opposite Wall in a Situation higher than the red, and the intermediate Colours in intermediate Situations, those which had suffered the greater Refraction in the first Prism, suffering the greater in the second likewise; all these Colours will paint upon a white Paper directly opposite to them, a little Circle perfectly round, and not oblong like the Image made by the first Prism, and this Circle will be of the same Colour as the Rays, without any Addition or Mixture.

I beseech you to stop and take Breath, said the Marchioness, you were ingaged in such a long Period, that I began to think

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think you would never get to the End of it. I should be sorry, Madam, answered I, if the Length of the Period has rendered me obscure, and made you lose so fine an Experiment. No, no, said the Marchioness, I understand it very well. Does not all your Meaning amount to this, that the homogeneous Rays of Light are immutable both with Respect to Colour and Degree of Refrangibility? I am extremely rejoiced, said I, to find I may be as prolix in my Periods as I please, without Apprehension of Obscurity, and may employ one as long as those of the *Azolain* Dialoguists, to tell you that this is the Experiment which Mr. *Mariotte* endeavoured to make, and by some Misfortune found that after the second Refraction certain new Colours were united to the red and blue. I know not how this happened, but probably it was from some Defect in the Prism which he employed.

The ill Success of this Experiment would have done the Immutability of Colour no small Injury in the learned World

World beyond Sea, if it had not been repeated in *England* before some learned *Frenchmen*, the Motive of whose Voyage was purely philosophical. This Repetition of the Experiment clearly demonstrated, that Mr. *Mariotte*, tho' otherways an accurate Observer, has failed in some of the Circumstances necessary to bring it to good Effect. Thus were these two Nations more divided by their different Ways of thinking, than by a little Arm of the Sea, reconciled upon this Point.

This Law of Nature common to all Nations acquainted with Light, met with a less favourable Reception in *Italy* than in any other. The most obstinate Antagonists of the *Newtonian* System have risen among us; there seems to be some Fatality in this, that a Nation which the *Italians* once found so difficult to subdue by Force, should in its Turn find us the most difficult to be subdued by Reason.

In order to contribute my Share to the Establishment of this Law even among us, I caused the same Experiment

ment to be repeated at a Place in *Italy*, celebrated for the learned Men it has always produced, and neuter enough not to be suspected of Partiality. No Minister of State, said the Marchioness, could act more politicly in the Choice of a proper Place for the holding a Congress. Within a very little, answered I, all my Politics would have signified nothing: For tho' we made use of Sir *Isaac Newton's* own Method in separating the Colours, and the Chamber was extremely dark, yet a certain Light of a blueish Cast always mixt itself with the Colours refracted by the second Prism. 'Tis true, this Light was irregular and inconstant, but however, it was sufficient to serve for an Excuse to the Incredulous.

This Appearance gave us a real Inquietude; and we would never have slept in Peace if we had not, after much Study, found out the Cause. We observed that the Borders of the coloured Image were not so well terminated as they ought to have been, provided the Prism, by which it was coloured, had been

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been good. We discovered a Light round the Edges of the same Nature with that which was observed to be mixed with the Colours réfracted the second time, and we perceived that several Streaks of this Light crossed the Image from one End to the other. From all these Circumstances it appeared, there must be several Irregularities in the Prism, as Bubbles of Air inclosed in the Glass, Unevenness in the Surface, and other Things of the like Nature, which were probably the Reason why the Light was irregularly refracted, and by this means rendered it impossible for the Colours upon the Image to be perfectly separated.

Various and repeated Experiments made it evident that the Fault of this apparent Alteration of Colours, which we observed in the Image, must be imputed intirely to that irregular Light which we had before suspected to be the Cause, if we may call that an Alteration which was nothing but the Addition of one Colour to another.

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I congratulate you, interrupted the Marchioness, that after such a Discovery nothing will hereafter disturb the Tranquility of your Sleep. Heaven preserve me, answered I, from that cold tedious Tranquility, which is however the Object of our Desires. 'Tis in Philosophy as in all other human Affairs, where the Accomplishment of one Desire often gives Birth to another.

When we had discovered the Cause of this Defect in our Experiments, our next Business was to find some Remedy for it. The Difficulty of acquiring it was a new Motive for our Labour and Inquietude.

Our Prisms in *Italy* are of no other Use than to amuse Children, or hang up as a fine Show in some Window in the Country, and not for the Service of Philosophers, who are often too exact for Artificers, and require a greater Accuracy than is in the Power of Art to bestow.

We resolved to write to *England*, which has its *Fawkeners* for Lapidaries, and its *Grabams* for Clock-making, where,

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where, in short, every Thing seems to be contrived for the Service of the most curious and importunate Naturalists, if Fortune and our good Genius had not unexpectedly furnished us with some which were just arrived from that Country. These we esteemed as sacred as the *Romans* did the Article or Shield which fell from Heaven in the Reign of *Numa*; and we could have wished for a *Mamurius* to make as many Copies of these as he had formerly done of that.

With one of these Prisms we renewed the Experiment, and the coloured Image painted by it, emerged so beautiful, so well terminated, and so lively, that the other seemed no more, when compared to this, than a rough Draught to a finished Picture. The Colours refracted by a second Prism remained so immutable, that neither the most penetrating Eye, nor even the *Zoilus* of the *Newtonian* System would have discovered the least Alteration.

Perhaps, said the Marchioness, Nature has reserved the Merit of demonstrating Truth to the *English* Prisms,
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that is, to those by whose Means she at first discovered herself. It would be a very curious Phænomenon, answered I, to observe such a Partiality in Nature, as for her to prefer such a Prism made in *London*, to one produced in *Murano*. But the Truth is, that if we consult her as we ought, she always answers the same, whether the Prism be *English* or *Italian*, provided it be good and well worked; and the Chamber, where the Experiment is made, extremely dark.

If all these Circumstances are rightly prepared, the Colours, tho' refracted three or four times, will remain unchangeable, neither more nor less with Regard either to Colour or Figure, than an Object exposed to a homogeneal Light, and viewed through a Prism. The Variety of Colours, the Change of Figure, and the Confusion discovered in Objects looked upon in this Manner, proceeds from nothing but their reflecting more or less all Sorts of Rays, which being afterwards differently refracted, produce all these Irregularities.

If

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If upon a Circle of Paper there fall at the same time the red of one Image and the blue of another, so that the purple Colour, composed of both these, may appear, it will, when examined through a Prism, seem divided into two separate Circles, the one red and the other blue; and the Reason of this Appearance is the different Refraction of these two Colours. If the yellow and green of two other Images should fall at the same Time upon the Paper, so that it would be illuminated with four Colours at once, it will appear oblong and divided by Refraction into as many Circles as there are Colours, and these Circles will seem placed upon one another. I know you are going to add, said the Marchioness, interrupting me, that if this Paper be exposed to the Light of the Sun, who contains every Sort of Ray in himself, it will appear of a Figure still more oblong, and painted with all the Colours of the Rainbow; whereas, if it be illuminated by only one homogeneous Light, it will alter

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neither its Figure nor Colour when observed through a Prism.

You must forgive the Weakness of human Nature, Madam, answered I, if we generally finish the Sentence we have begun. It was reserved for Sir *Isaac Newton* and you, to understand Nature by half a Word, and find out Natural Philosophy, notwithstanding its Uncertainty. It is superfluous to tell you that Flies and other little Objects, placed in a homogeneal Light, appear very distinctly to the Eye with a Prism; and the very smallest Elziver Print may be read without any Difficulty, But the same Things will not have this Effect when placed in the heterogeneous Light of the Sun, because of the Confusion and Quantities of Colours that arise.

In this Case I abandon the Prism to the Disposal of Poetry, to make Use of it in Comparisons, which do it no great Honour. That celebrated Author, whose fine Ode you so much admired, compares it to false Eloquence which obscures the Face of Truth, lavishes its
Orna-

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Ornaments without Distinction, and diffuses its glaring Colour over every Thing. It is certain that the Poet in this Comparison, means that Prism which transmits the Rays of every Sort. And when it transmits only the homogeneous Rays, said the Marchioness, may we not compare it to true Eloquence and true Spirit? For as it shews us the Objects removed out of their Place without any Alteration, so true Wit often surprizes us only by varying common Subjects in a new Manner.

You are so well acquainted with the Prism, answered I, that you may safely compare it with your own Wit. But I know not what Comparison you will find for the Immutability of Colours, unless you seek for it perhaps in your own Heart; and then knowing that Reflection has no more Influence on that Immutability than Refraction has, you will be better acquainted with it than you at present are.

If the Colours with which Bodies are variegated and painted were only a Modification, which the Rays of Light

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acquire by being reflected from their various Surfaces, as was once believed, a Body which appears red in the Light of the Sun, would still remain red when placed in any other Colour of the painted Image, for Instance, *blue*, because it could modify this blue Colour refracted and modified already by the Prism, as well as it does the Light which comes directly from the Sun.

But Sir *Isaac Newton* has proved by Experiments, that every Body placed in homogeneous Rays is of the same Colour as the Rays themselves, without allowing, however, the Supposition that Bodies by Reflection modify the Light in such a Manner, as to make it receive this or that particular Colour. Thus all white, red, yellow, blue, green Bodies, as Paper, Scarlet, Gold, *Ultramarine*, and Grass, in red Rays appear totally green, in blue, totally blue, and so of the rest. The only Difference consists in this, that all these various Bodies placed in the same homogeneous Light, are not all equally luminous, but every Body appears the most lively when placed

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placed in a Light of its own Colour, except Paper, and all other white Bodies which equally receive any Colour, and may be regarded as the *Cameleon* and *Proteus* of Optics.

Would this Diamond then, interrupted the Marchioness, if placed in the Rays of our coloured Image, take indifferently any Colour, and at one Time be transformed to a Ruby, at another to a Topaz, an Emerald or a Sapphire? So much the better, answered I, as it would dart only one unmixed Colour, and all the varying Splendors with which it sparkles in the direct Light of the Sun, would vanish in this homogeneal Light.

It is very pleasant to observe how the fine Dust or Atoms in the Air change Colour as they pass from one Ray to another, just as a River varies its Colour according to the various Qualities of its Bottom.

Other Bodies, as I before mentioned, are not equally lively when placed in different coloured Lights. The Varnish, for Instance, with which *Martino*,

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the Emulator of the *Chinese* Art, makes so many fine Curiosities, is extremely luminous in the red Light, less in the green, and still fainter in the blue. On the contrary, the *Lapis Lazuli*, which has the Honour to serve for a Repository to your Snuff, is extremely lively in the blue, less so in the green, still fainter in the yellow, and almost dark in the red.

The same Inequality holds good in Bodies seen by a transmitted Light, as is proved by Glasses of different Colours; so that every Body reflects or transmits in great Abundance, those Rays which are of its own Colour, and reflects or transmits the other Rays, in Proportion as they are nearer or farther off its own Colour in the Order of Refrangibility.

It follows from hence, said the Marchioness, that no Colour even that seems the most perfect, can be absolutely unmixed. And perhaps it will never be in the Power of Art to dye a Silk in such a Manner, as for it to reflect only one Sort of Rays.

It would be more difficult, answered I, to sort the various Colours together,
and

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and flatter our Sight by the Concords of Harmony, if they were all homogeneous and unmixt. In this Case, all the Delicacy of Nature would be requisite to find out the innumerable intermediate Shades betwixt any two Colours. But now as every Colour is more or less blended with some other, we are by that Means furnished with a much more easy and expeditious Way.

Hence it is that the Gradation from one Shade to another (tho' perhaps there may be several intermediate ones wanting) does not appear defective to our Eye, which discovers in each the same Basis of all the Colours that softens them; and serves for a Support to the Harmony.

There would arise other Inconveniences besides these, if coloured Mediums did not transmit every Sort of Ray; for this would aggravate a Distemper bad enough in itself, which infects and tinges the whole Body, and the Eye itself with an unpleasing yellow.

Persons under such Circumstances as

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these

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these, when it is very improper to pay Visits to Ladies, would become absolutely blind, unless to yellow Objects, and could see no Faces but of those who are troubled with the same Disorder.

A perfectly complaisant Lover, replied the Marchioness, if his Mistress should happen to be ill of this Distemper, must cloath himself in yellow, (a Colour which tho' regarded with great Veneration in *China*, is not looked upon as a good Omen for Lovers among us,) and perhaps get the Jaundice in order to be seen by his Charmer, and give her a Proof of his Affection.

So perfect a Lover, answered I, would not be an improper Person to prove this Immutability of Colours, if we had no more Proofs to demonstrate it than what you have already seen. What remained to be shewn was, whether the Confines of Shadow, with which the Light is bounded, are capable of making any Alteration in the Colours? This would have been fine Sport for those
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Naturalists who lay hold on every thing, in order to build a System.

Our Philosopher put the Colours to the Test of this new Experiment, and found nothing wanting in their Constancy which maintains its Ground, even when it happens that Rays of different Colours cross and intersect each other; it appears, in short, to defy every thing judg'd capable of bringing any Alteration upon them.

We must have Recourse to Romance, said the Marchioness, to find some equal to these Colours, which do not give Place even to the *Ephesian Anthia*, a Model of the firmest and most obstinate Constancy, in Spite of all that a Romancer can produce to make her at length — What? answered I, resemble the Matron her Fellow-Citizen, reply'd the Marchioness. The Constancy of these Colours must certainly appear very surprizing to Ladies, answered I. I do not doubt but the greater Part of them would much sooner admit the System of *Lucretius*, who, without so many

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Experiments, affirmed not only that they are mutable, but that any one Colour may be changed into all the rest.



The

The FIFTH BOOK.



THE next Morning, as soon as the Marchioness was up, she sent for me into her Closet, not concealing that agreeable Disorder which she knew her Beauty could receive no Injury from. I find indeed, said she, that your Philosophy begins to grow a very serious Thing. I can assure you, I have slept much less this Night than before. I cannot tell whether this be the Reason of it, but I find that Philosophy and sound Sleep do not agree very well together. My interrupted Dreams have transported me into the Region of Optics, where I saw nothing but Prisms, Lenses, Rays differently refracted, coloured Images, in short, all those Experiments, and all that philosophical Apparatus which you described, arose successively in my Imagination like

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like Visions and Fantomes. Whatever Charms these Things may have in themselves, I could never have imagined they would employ my Thoughts so strongly at a Time when it is not very customary to think of Philosophy. No really, answered I, it was a Time more proper to think on the Philosopher. You are not to suppose, replied the Marchioness, but he had his Share, and has no Reason to complain of me. If this be the Case, Madam, answered I, there is no great Mischief done. I rather advise you to recal these Dreams to your Memory as often as you can, and you will be still the more sensible that they deserve it. How do you suppose it possible, continued she smiling, that I could think on these Experiments, without admiring the Penetration and Ingenuity of the Philosopher who invented them, a Man who seemed directed by Nature herself, in the Method of tracing her Laws? I perceive, said I, that you take the Thing too seriously. In the present Case I think you might be contented with the Expofitor.

How

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How can I be too serious? replied the Marchioness. We are examining whether Colours be immutable or not, whether the Rays of Light be differently refrangible, we are building up and throwing down Systems, and in short, our Inquiries aim at nothing less than Truth itself. Can you reasonably accuse me then of being too serious in Matters of such Importance? But these Systems, answered I, and this Truth, however pompous they may sound to the Ear, ought not, however, to disturb our more agreeable Dreams. It would really gain me a fine Reputation in the World, if it were publicly known that I had made you dream of Lenses and Prisms. We should act in Things of this Nature, as those who study to make the best Use of their Passions, do with Regard to Love. These Persons (who do not appear to be the most injudicious) never devote themselves so intirely to it, as to interrupt their more important Concerns, but only as much as is sufficient to make them pass away two or three Hours agreeably

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agreeably with that Sex with whom it is hardly possible to converse upon good Terms, without at least a Pretence of being in Love.

You at once give me Lessons in Love and Philosophy, replied the Marchioness. But you know when People first fall in Love, they have little Leisure for these grave Reflections, but suffer themselves to be transported farther than they ought. This is exactly my Case with regard to Philosophy, in which I have hardly yet advanced one Step. I am so little Mistress of myself, that I have gone so far as to seek Methods to confirm Sir *Isaac Newton's* System. After all you have told me, judge whether my Transports were not very strong.

Let us see, Madam, answered I, what they have produced, for we often owe the finest Things to strong Passions. The *Iliad*, *Æneis*, the Poems of *Dante* and *Milton* were produced in their most vigorous Time of Life. To these may be added (at least for that Veneration with which they are regarded by their

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Countrymen) the *Lusiade* of Camoens, composed in a Time of the greatest Revolutions and Conquests in Portugal, and the *Araucana* of the Spaniards, where the Poet himself is the Hero. Perhaps between the broken Slumbers of last Night, your Imagination produced something greater than all I have been mentioning.

I am afraid, answered the Marchioness, that it will amount to very little. I was thinking, that if Light is composed of Rays of different Colours, which blended together, produce *white*, we ought to examine whether these Colours, after being separated by the Prism, might not be mixt together again. I for a long Time considered, but with little Success, in what Manner this could be effected.

Sir *Isaac Newton* himself, said I, has delivered you from this Trouble; for that Method of confirming his System which you mention is so good, or rather so evident and immediate a Consequence of Order, that he has made several Experiments to that Purpose.

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I am now going to shew you one of the most celebrated, and at the same Time the most simple, to which this great Philosopher was conducted by that Spirit of Order which you possess in common with him.

The Image of the Sun made by a Prism in the dark Chamber, is received upon a Convex Lens, that the coloured Ray, which at going out of the Prism, diverged, may by the Lens be made to converge and unite, and by this Means be again blended together. I am quite ashamed both of my Stupidity and myself, interrupted the Marchioness. I had all the Materials necessary for the Execution of my Idea, ready prepared to my Hand; they only wanted putting together, and I had not the Sense to do it. You were greatly in the Right to be unwilling that a Person should hear the Voice of Philosophy, who is incapable of making it an Answer. I might rather, answered I, apply to you that famous Saying of Antiquity, *I wish with all these Qualifications, you were one of us.* You will find in Optics themselves,

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felves, some Consolation for what you call your *Stupidity*. Men, those reasonable and curious Beings, lived above three hundred Years before they found out that a Convex and Concave-Glass put together, would make a Telescope; and tho' they had the Materials every Day at Hand, were at last indebted to mere Chance for this useful Instrument. It was a greater Disgrace to Mankind not to discover it before, than Honour to them that they found it at last. So that this useful and fine Invention is of the Number of those which are standing Monuments of the Weakness of human Nature. You comfort me, replied the Marchioness, at the Expence of Mankind. — But to return to our Subject. I suppose that Point beyond the Lens, where the coloured Rays are united, will appear totally white.

The Rays, answered I, have no sooner passed through the Lens, but they begin to mix and efface each other; and they lose the fine harmonious Proportion established betwixt them in the Spaces of the coloured Image, the Original of
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the Music of the Eyes. When they are all confined at length, and incorporated together in the Focus of the Lens, they form a little circular Image totally white, a Republic (if I may use the Expression) of Colours, where they are all equally tempered together: The red can no longer display its lively Flame, the green boasts no more the smiling Livery of the Spring, nor the blue the lucid Robe of Heaven, but all blended together, restore the Whiteness of the Sun from whence they came, in such a Manner, however, that as they recede from the Focus, they again renew their Splendor and Colour, but in a contrary Order, and the ravished Eye again wanders from one Pleasure to another.

You will easily understand how they come to be inverted, if you remember the two Sticks crossed together, mentioned by *Des Cartes*, which you once believed to have a greater Efficacy in explaining the Phenomena of Optics than they really have. The Appearance that the Colours again make beyond.

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yond the Place where they were blended, demonstrates that the Rays lose neither their Colour nor Quality, as some might perhaps believe, but that the Whiteness which appears in the Focus of the Lens, is produced only by their Mixture.

I now understand, said she, what you meant Yesterday by saying, that the Immutability of Colours still remains, even when Rays of a different Colour intersect and cross each other; for if it were otherways, we should not see the prismatic Colours re-appear beyond the Place where the Rays united.

This is the very Experiment, answered I, upon which the Immutability of Colours was grounded; and all the Experiments of Sir *Isaac Newton* have this peculiar and admirable Quality, that each single one is not contented with demonstrating only one Thing, as is the Case of most others, but demonstrates many more at the same Time. This arises from the close Union, and almost Geometrical Connexion

nexion which the Properties of Light have between themselves.

Sir *Isaac Newton's* Experiment, said the Marchioness, seems to resemble the Battles of the Ancients, which often gained the Victor a great Number of Provinces at a Time. And those of most other Philosophers, answered I, the Battles of the Moderns, the most noisy Preparations, the most consummate Contrivance, and the Blood of Millions, amount to no more than the taking a Place, which perhaps might have surrendered in two Months by a Treaty.

But to return to your Experiment. I call it *your's*, because tho' you did not invent it, you saw the Necessity there was for its Invention in order to compleat the System. Our Philosopher never quitted it till he had varied it a thousand Ways.

It was necessary to prevent some one of the coloured Rays from passing through the Lens, in order to see whether the Whiteness of the little circular Image would by that means be changed.

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This Sir *Isaac Newton* did, and intercepted the Passage sometimes of one Colour and sometimes of another; and the Whiteness ceased, and degenerated into that Colour which arises from the Composition of those Colours which were not intercepted, but suffered to pass through the Lens.

The Want of any Colour in the circular Image, which is not suffered to pass, will be very agreeably discovered by looking thro' a Prism, which resolves the Image into its component Colours, by giving them a different Refraction.

If all the Rays be transmitted thro' the Lens, the Image will be white; but viewed through a Prism, it will appear of all Colours like the Rainbow: If any Ray be intercepted, this by the Prism was discover'd to be wanting in the Image, till at last suffering only one Colour to pass thro' the Lens, this one Colour too was seen by the Prism.

If all the Colours were successively intercepted by the Teeth of a Comb made to pass very swiftly over the Lens, the circular Image would remain white,
and

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and the different Colours not be distinguished, by Reason of the quick Impression which they all successively make upon the Eye.

You may perhaps have observed, that when a lighted Torch is moved nimbly round in a Circle, the whole Circle which it forms in the Air, appears on Fire; and the Reason of this is, because the Sensation (which in the several Places of that Circle it raises in the Eye) remains impressed till the Torch returns again to the same Place.

In the same Manner (when the Colours follow one another with an extreme Rapidity) the Impression of each of them remains in the Eye, till a Revolution of all the Colours be completed. The Impressions therefore of all the successive Colours are at once in the same Part of the Eye, and jointly excite the Sensation of Whiteness there.

The same was afterwards proved by a Wheel, whose Circle, painted with the several Colours of the Prism, appeared white, when turned very rapidly round itself.

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I must confess, said the Marchioness, that even if I could have found the Experiment I sought for, I should never have been able to diversify it so many different Ways, tho' the Inconstancy which you, Gentlemen, lay to our Charge, might perhaps have given me no small Assistance.

This Inconstancy, answered I, which perhaps is not so great a Defect as some believe, was not wanting in Sir *Isaac Newton*. With the most fertile, and almost poetical Imagination, he continually invented new Experiments, which tho' different from each other, all concurred to prove the same Thing. They seemed to rise under his Hands as the Poets make Flowers spring under the Feet of their Beauties.

The coloured Image formed by the Prism becomes white, when viewed thro' another Prism, in such a Manner, that it contracts the Image and mingles the Colours. I have observed the same Phænomenon in the Rainbow, which is the Effect of a Separation of the solar Rays in the Drops of Rain
opposite

opposite to the Sun. It appears white when viewed thro' a Prism, turned in such a Manner, as to contract it and blend the Colours together.

Those who live near the Cataracts of Rivers, see a Rainbow every Day, when the Sky is clear, formed by the Sun in the dashing of the Water against the Rocks; making People have the Opportunity of seeing this Experiment much oftner than we can.

I would, if possible, replied the Marchioness, have nothing to envy others. Tho' we have no Cataracts, a Fountain will imitate the Rain, present us with the Colours of the Rainbow, and we may make our Observations at Pleasure. We will call this Fountain, if you think proper, *The Fountain of Optics*.

Till your Garden furnishes you with Proofs of the *Newtonian* System, answered I, as the Gallery did with Objections against the *Cartesian*, you may return to the dark Room: There you will see that the Whiteness of a Paper placed over against the coloured Image
of

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of the Sun, does not suffer any Alteration, if it be placed in such a Manner as to partake equally of all the Colours: Whereas, if it approaches nearer to one than another, its Whiteness will be tinged with that Colour which is next it. Is it possible now for Truth to descend from Heaven with a more shining Train of Proofs?

I was very confident, said the Marchioness, to venture my Thoughts upon a Thing which cost Sir *Isaac Newton* so much Study. How is it possible I could ever have found out the very least of these Experiments as easy and simple as they now appear? But in Exchange, answered I, you can easily invent Things that perhaps would have puzzled the Philosopher. It is much more proper for you to know in what Proportion to mix Hope and Fear, Smiles and Frowns, to prevent a Lover's Passion from growing languid, than to be exactly acquainted what Quantity of different coloured Powders is necessary to be mixed together to form a white. This is another Experiment

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which

which our Philosopher tried, that there might be nothing wanting to confirm his System. It is true, the white which arises from this Composition is dusky, grey, and obscure, like the Colour of Ashes: And the Reason is, because the Colours of these Powders are too imperfect and faint, compared with those of the Prism, to make a lively clear white.

However, if this Mixture be exposed to the Sun, in order to increase the Force of the Light, that dusky obscure white will become bright and clear, tho' it will never equal the Strength of the Paper exposed to the same Light.

For this Reason in coloured Prints, one of the finest Inventions of our Time, which, with only three Colours, perfectly imitate all the Variety of Painting, the Paper is left uncovered for *strong Clears and Whites*.

Water thickened with Soap, and agitated so as to raise a Froth, is more proper to demonstrate that a Composition of Colours produces white. After the Froth is a little settled, there will appear upon the Surfaces of the Bubbles
of

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of which it is composed, different Colours, which when viewed at a Distance cannot be distinguished from each other, and the whole Froth will appear perfectly white. This Experiment has, besides its being an agreeable one, this further Advantage, that it is very easy to make.

Philosophy, said the Marchioness, from what I can discover of it, is like a Game of Chess, which upon any other Occasion I should make no Scruple to call an ingenious Pretext to waste Time. The very least Piece in the one, and the least Experiment in the other, is often of the highest Importance. A Pawn in the Hand of a skilful Player may give Check Mate, and a little Froth will furnish Sir *Isaac Newton* with a whole Magazine of Observations and Discoveries. Half the World that preceded him had the same Bubbles and Froth before their Eyes, without so much as seeing them. The Ancients themselves would a thousand times have observed and neglected them.

The Eyes of the Ancients, answered

I, were much better able to judge of the Elegance of a Statue or a Temple, than the Importance of an Experiment. *Seneca* was acquainted with a Sort of Prism, which receiving the Light of the Sun on one Side, displayed to the Eye the Colours of the Rainbow. All the Explication which he gives of this Phænomenon is, that there is really no Colour, but only the Appearance of a false Colour like that on the Neck of a Dove, which appears and dis-appears according to the Motion of the Eye and the Change of its Situation. This fine Explication sufficiently shews how very little the Ancients studied Nature and pursued her Steps; for if *Seneca* had taken the least Trouble to examine his Prism, he must have seen the Difference between the Colours produced by that, and those on the Neck of a Dove.

A particular Sort of Microscope known to this Philosopher, and which perhaps the ancient Artificers made Use of in the curious engraving of their Intaglia's and Cameo's, the Enigma and Admiration of our Time, this Micro-

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cröscope I say, composed of a Ball of Glas filled with Water, had no better Fortune in his Hands than the Prism. He ascribed the magnifying of the Objects viewed thro' this Glas to a Quality of the Water, and not to the Figure of the Glas which contained it.

The Weight and other Properties of Air were known to the Ancients; and in order to explain how Water ascends in a lifting Pump (which is occasioned by this Weight of the Air) they had Recourse to a certain imaginary Horror that Nature has for a Vacuum: So that rather than leave the smallest Space empty, she chose to violate her own Laws of Gravity, and make the Water ascend. And as one Folly produces a thousand more, the great Horror that Nature testified for a Vacuum in this Pump, extended only to a certain Height, and beyond this perhaps was changed into Love, for there she admits as great a Vacuum in the Pump as you could desire.

But to quote still more Examples ---

Nero in his golden Palace (one of the most magnificent Effects of despotic Power in the Universe) erected a Temple of Stone so very transparent, that Day-Light entered into it even when the Doors were shut. *Pliny* who gives us this Relation, instead of contenting himself with affirming that it was more transparent than Alabaster, says, that it did not transmit the Light like other pellucid Substances, but included it within itself: If this had been the Case, the Temple must have appeared much more luminous by Night than Day.

The Ancients were fonder of what raised their Admiration than increased their Knowledge; and perhaps thought Experiments (which are the only Method by which we can arrive to a true Admiration of Nature) were too material to imploy the Attention of a Philosopher, who ought to consult nothing but Reason. They never imagined these Experiments would one Day lead industrious Posterity to such an Exactness as to subject Flame to the Examination

nation of a Balance, which was antiently regarded as a light Substance, for whose Sake they invented a particular Sphere of Fire where it was affirmed to ascend.

Nor could they foresee that these Experiments could help us to calculate how much we daily lose by a continual insensible Perspiration, how many million Tons of Water the Mediterranean Sea perspires in a Summer's Day, how much a Man decreases by the Weakness of the Muscles from Morning to Night? In short, that they should inable us to counterfeit Nature herself; and by certain chemical Mixtures emulate her *Etna's* and *Vesuvio's*, and imitate her Thunder much better than their own rash *Salmones*.

If an Antient had been asked whether the Phosphorus of *Bologna*, for Example, shines by its own Light, or by a borrowed one, it is impossible to know. how many ridiculous Fancies they would have uttered by consulting Reason; whereas a Modern with a single Experiment has put the Matter out of all

Question. Pray what is this *Phosphorus*, said the Marchioness, this Subject of the Absurdities of the Ancients and Experiment of the Moderns? It is a certain Stone, answered I, found in a Mountain near *Bologna*, which calcin'd with Fire, acquires the Property of shining in the dark like a Coal, if it has been exposed a little while to the Light of the Sun, or only to the open Air. From this Quality it has obtained the fine *Greek* Name of *Phosphorus*, which signifies a lucid Body. This is an Honour given almost to every Thing appropriated to learned Uses. An Etymologist could not perhaps give a better Name to this Place than that of *Phosphus* (which in our Language signifies the *Lucid Hill*) and would thus consecrate it for ever to Philosophy and Learning. We are much obliged to your Scholar, said she, for conferring so fine a Name on this Place which certainly deserves it.

The Question, continued I, is at present reduced to this, whether the *Phosphorus* only takes in and imbibes the
Light

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Light to which it is exposed, and from thence carried into the dark, shines with a borrowed Light, or whether the external Light puts its Parts into such an Agitation as to kindle a Light which it contains within itself, which by this means loosed from its Prison, if I may use that Expression, emits itself from the Phosphorus, which in this Manner shines by its own Light. This last Supposition is more honourable for it, and better agrees with the fine Name it bears.

In order to decide this Point, a modern Philosopher chose a Sort of Light which would shew whether the Phosphorus, when exposed to it, imbibed any of its Rays, and by that means reveal the Theft of this new *Prometheus*. I already see, interrupted the Marchioness, how this Modern proceeded. He placed the Phosphorus in one of the Colours of the prismatic Image, in order to see whether it would acquire the Colour as well as the Light: If it did actually take the Colour, it is evident that it imbibes the external Light, and shines with a Splendor not its own:

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But if it does not take the Colour of the Image (since Colours are immutable and suffer no Alteration) the Light only agitates its Parts, and as you express it, loses its Splendor out of Prison; and thus the Phosphorus shines not by a borrowed Lustre but its own, and ought rather to be compared with the Sun himself, than *Prometheus*.

It is too true, answered I, that fine Ladies can be just what they please. You would be extremely in the wrong, if you hereafter complain of any Want of Sagacity in Physics. What you have been describing is the very Method which the *Bolognese* Philosopher took; and by this Experiment he confirmed to his Fellow-Citizen the *Phosphorus*, the Honour of shining by its own Light. It is probable that the innumerable other *Phosphori* of the same Nature, lately discovered in *France*, owed their Lustre to the same Cause: These, by enriching Philosophy with new Wonders, have deprived the *Bolognese* of the Honour of Singularity, which is partook with only one other in the whole philosophical World.

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World. Do not Diamonds, the most valuable Phosphorus of Nature, shine in the dark, because the external Light kindles, and revives the internal Light, of which they are a rich and inexhaustible Treasure?

You may judge, replied the Marchioness, of my very great Sagacity in philosophical Affairs, when I never observed a Phænomenon which I every Day carry about me. Perhaps, Madam, answered I, you were never in a Place dark enough to make this Observation. *Signore Boccari* one Day visited a Lady in some Indisposition, who was resting behind a Screen far from the Air, and in a Place absolutely dark. The Lady asked him whether he had not a Light in his Hand; which he denied; but she constantly insisting she saw something glitter, the Doctor at last suspected it to be his Ring which shone in that profound Darkness, and perceived he had a long Time, without knowing it, carried a Phosphorus upon his Finger. You may judge of the Value he afterwards set upon this Ring. He made
innu-

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innumerable Experiments with it about the Time that Mr. *Du Fay*, Father of so many Phosphori, found that Diamonds had the same Property. How empty and barren must the Philosophy of the Ancients have been, said the Marchioness, and how copious, how charming is ours, whose Observations enhance even the Value of Diamonds?

I will give you still greater Evidence, answered I, how much the Ancients were to blame in their Neglect of Experiments, and you will be fully convinced that there is none even of those which seem of least Importance, but what is of great Service to Natural Philosophy. That Froth we lately mentioned is an Instance of this, for as little philosophical as it may seem to vulgar Eyes, it was the principal Thing by which Sir *Isaac Newton* found out the Cause of those various and almost innumerable Colours which we see in Bodies.

He had discovered in general that certain Bodies appear of a certain Colour, because they reflect one Sort

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Sort of Rays more copiously than the rest, and other Bodies of different Colour, because they reflect a different Sort; so that if Light consisted of only one Sort of Rays, there could be only one Colour in the World, nor would it be possible by Refractions and Reflections to produce any new one.

This Discovery, which would perhaps have satisfied any other Philosopher, served only to excite the Curiosity of ours, and was but a Prelude to innumerable others.

Why should this Silk reflect the blue more freely than any other Sort of Rays? The Reason is this.

If one of those Bubbles which are formed by blowing Water a little thickened with Soap, be covered with Glass in order to prevent its being agitated by the Air, it will appear tinged with a great Variety of Colours, which spread themselves like so many Rings one within another, and incompass the Top of the Bubble. And in Proportion as the Bubble grows thinner by the continual subsiding of the Water, these Rings slowly

slowly dilate and overspread the whole, descending in order to the Bottom of it, where they all afterwards successively vanish.

The Variety of these Colours depends on the unequal Thickness of the Bubble of Water in different Parts. But how to determine these Inequalities is not so easy, and perhaps would have been impossible to any but Sir *Isaac Newton*, who examined these Rings a thousand ways, guided by his constant Tutor Geometry, and a Spirit of Observation, whose Fertility seemed to increase in Proportion to the Difficulties it encountered.

He discovered that a certain determinate Thickness is necessary in a Plate of Water, (for Example) in order for it to reflect a particular Colour, and a different Thickness to make it reflect any other Colour, and in general, that a less Thickness is necessary to reflect the most refrangible Rays, as violet and indigo, than those which are least refrangible, as red and orange; all this is to be considered with Regard to a Substance

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stance of equal Density. But when the Density in one Substance is less than in another, as the Density of Air compared with that of Water, a greater Thickness will be necessary in the first than in the last, to reflect the same Colour.

After the same Manner he defined the Thicknesses necessary for the Transmission of Colours. From the Analogy or Similitude between the Plates of Substances which he considered, and the Particles of which Bodies are composed, he demonstrated that their Colours depend on nothing but the different Thicknesses and Density in their Particles, whence it follows that some are more proper to reflect or transmit the Rays of one Colour, and others those of a different one.

This Analogy holds good in many Instances. Thus the one and the other are transparent: The Leaves of Gold and the Particles of many other Bodies transmit one Colour and reflect another, just as the Bubbles of Water which we have been mentioning: These Rings
appear

appear of a various Colour when viewed in different Situations; the same happens in certain Silks, in the fine Web of the industrious Spider, and as *Tasso* sweetly sings.

The Feathers so, that tender soft and plain

About the Dove's smooth Neck close couched been,

Do in one Colour / never long remain,

But change their Hew 'gainst Glimpse of Phætus Sheen.

And now of Rubies bright a vermeil Chain,

Now make a Cariket rich of Emeralds green,

Now mingle both, now alter, turn, and change

To thousand Colours rich, pure, fair, and strange.

FAIRFAX'S *Tasso*.

This appears very evident in those Powders that Painters make Use of, for when they are groun'd, (that is when their Parts are subtilised) their Colours change

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change a little. Bodies may in some Measure be regarded as Stuffs, for their Threads, every one in particular reflecting a particular Sort of Rays, the whole Stuff appears of that Colour which is the Result of all the Rays reflected from the several Threads of which the Stuff is composed.

But what becomes of those Rays which are not reflected? said the Marchioness. Can you give an Account of them? They are either transmitted, answered I, or stifled and extinguished, and are thus lost among the Particles of Bodies. A Leaf of Gold placed between Light and the Eye is transparent, and appears of a greenish blue; but a Collection of these Leaves placed one upon another loses both Colour and Transparency, the Rays which pass thro' the first Leaf being absolutely extinguished in passing successively thro' the rest.

White Bodies (to continue our Similitude) are Stuffs composed of Threads which reflect all Colours; black, on the contrary, absorb and extinguish every
Sort

Sort of Ray within themselves. For this Reason black Bodies heat much more easily than any other; and a black Cap, such as the *English* Ladies wear in St. *James's* Park, would not at all agree with your Walks in the *Italian* Sun.

White Bodies as they reflect and drive every Sort of Ray from them, heat with more Difficulty than the others which imbibe and absorb the Rays, and neither transmit or reflect them.

From the same Causes arise the various Colours which we discover in the Air. The different Density and Thickness of the Exhalations and Vapours that rise from the Sea and Earth, paints the Heaven with varying Splendors, when rosy-fingered *Aurora* opens the Portals of the Morning, and calls back Mortals to their several Labours, or when *Vesper* invites them to an agreeable Repose; it is difficult however, to trace a Cause by which the Colours at the Rising and Setting of the Sun are almost all the same, and succeed each other in a certain Order. But this we certainly know,
that

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that the several Colours of different Persons Eyes proceeds from the Difference of Texture in the *Iris*, which is that Coat in the Eye that incompasses the Pupil.

The Variety of Fibres in the *Iris* kindles in some the imperious Look of a black Eye, in others the insidious Sweetness of the blue. But it is not easy to assign a constant Cause why the Northern Nations should generally have white Hair and blue or grey Eyes, and we of a warmer Imagination, not in a warmer Climate, should have our Eyes black as our Hair.

This System however, will give us the Explication of a Phænomenon which is perhaps inexplicable in any other, and will thus make us a Compensation, for not being able to give a Reason for every thing in particular.

The Phænomenon is this: Two transparent Liquors, the one red and the other blue, cease to be transparent when we look thro' both at the same Time. This Phænomenon which so greatly surpris'd the Person who first observed it,

it, is only a Consequence of the *Newtonian* Doctrine. The one of these Liquors transmits only red Rays, and the other only blue. Hence it follows, that the Rays transmitted by the one will be extinguished and absorbed by the other, and the Eye which looks through each of them receive none. And this Phænomenon is one of those whose Explication becomes a Demonstration of the System which is capable of explaining it.

That Opinion, said the Marchioness, that blind People can distinguish Colours by their Feeling, now begins to appear credible to me: Or rather, is it not another Proof of our System? If our Feeling was finer than it is at present, as fine as that of blind Persons perhaps is, could not we discover the Colour of a Body by feeling the different Thickness of its Particles? And thus we should effect by our immediate Sense, what a *Newtonian* would by his Calculations, if any one should acquaint him with the hidden Texture of Bodies.

Your blind Observators, answered I, might

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might distinguish Colours by their Feeling, even in the *Cartesian* System which you have now given up. For according to that, there must be a Difference in the Particles of Bodies of different Colours in order that the Rays of Light may be differently modified. A Proof like this you perceive is too ambiguous to deserve a Place among those we have already mentioned; and there is the same Defect in what is said of a singular Kind of Barometer, which the *Chinese* make Use of to form a Judgment of the Weather by. This-Barometer is a Statue placed upon a Mountain, which foretels the Changes of the Sky and Air, by varying its own Colour.

But had we not better seek for a Phænomenon nearer ourselves in the Nation of Gallantry and Politeness, which can be explained by the *English* System alone? Why should the Belles of that happy Country lay on more red when they appear in the Boxes at an Opera, than when they embellish with their Charms the agreeable Walks of the *Thuilleries*?

You

You lead Sir *Isaac Newton's* System, said the Marchioness, into Places where you would have found it very difficult to lead its Author. Not if you, Madam, answered I, had been there.

The Light of a Candle is not so white as that of the Day; it has a yellowish Cast, and viewed thro' a Prism, yellow appears the most shining Colour in it. The less then the *Spanish* Wool is charged, or in other Words, the more it reflects other Rays besides the red, the stronger will the yellow appear, which is the predominant Colour in this Sort of Light; just as in a Chamber where the Light enters thro' coloured Curtains, the Objects in the Chamber will the more easily take the Colour of the Curtains in Proportion as their own Colour is weak and faint. This is evidently a Reason why the Quality of *Spanish* Wool should be augmented for the Opera, that neither the Cheeks of the Ladies, nor the Eyes of their Admirers may lose any thing, but find the same Advantages by the Light of the Evening as by that of the Day.

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In the *Cartesian* System this wise Precaution would be entirely useless; for if the *Spanish* Wool can modify the Light of the Day, it would in the same manner modify that of the Evening, be it of what Colour it will.

Must it not be a Mortification, said the Marchioness, for the Ladies of this happy Climate (if they ever have Time to consider it) not to have a System in their own Country able to explain this Phænomenon in their Vermilion, but be obliged to call a foreign one from beyond Sea to their Assistance? So much the more glorious is it for this to extend its Empire over all Nations, even so far as to give them Lessons for the Toilet. This is not the only one, answered I. If you would not have a blue appear green by Candle-Light (which might disconcert the Harmony of a Suit of Cloaths, and cause innumerable Chagrins) you must be careful to chuse it very clear, otherwise the blue Rays mixed with the yellow, which the Silk would reflect in greater Quantities by

Candle-

Candle-Light, might perhaps make it appear green.

These are the *Gordian* Knots of the Optic Science, which this System dissolves without eluding the Oracle. These Phænomena inexplicable to every other System, are without Difficulty explained in this. Every ambiguous Explication, every Proof that has not the Force of Demonstration, is intirely rejected by the *Newtonian* Philosophy.

An Analogy, for Instance, discovered between the Production of Colours and that of other Things, which would supply another System with a Proof, can serve only for Ornament and Luxury to this.

It has been lately discovered that Insects, Men, Animals and Plants, instead of being continually re-produced by Nature, only unfold themselves from their respective Plants or Seeds (in which they are really contained) whenever they find a proper Disposition for it; that is, both Animals and Plants wait for a proper Repository, certain Juices, Degrees of Heat, and other Things requisite to unfold

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fold them. In the like Manner Colours are not, as was once believed, produced at every Refraction, or Reflection, or some other similar Cause, but unfold themselves, if I may use the Expression, from the Bosom of Light, which contains them within itself, whenever it is refracted by a Prism, or reflected from the Particles of Bodies. And this Method of their Production seems much more agreeable to the universal Laws and established Order of Nature.

After the same Manner appears the Colour of the Rainbow, the coloured Circles sometimes seen round the Sun and Moon, and those of a certain Light, which is often seen towards the Northern Parts of Heaven, and called *Aurora Borealis*.

Whatever Riches and Magnificence, replied the Marchioness, Nature has displayed in so great a Variety of Colours, she seems to have observed some Frugality in their Production. At least the *Newtonian* Nature appears to me a better OEconomist than the *Cartesian*. The first has made Light a Magazine

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and Reservoir of Colours, which she produced once for all insusceptible of any Alteration, only with a certain Disposition that renders them capable of being separated from each other, and shewing us by this Separation a Colour, which all united and mixed together, they could not do; whereas the *Cartesian* Nature is every Moment obliged to give new Rotations to her Globules, and at every Refraction and every little Circumstance, consider in what Manner to vary them. This must be an infinite Fatigue to her, and a very great Application of Thought.

But these Dispositions, answered I, which the Colours have to separate themselves, and which you so greatly admire, however convenient they may be to Nature by sparing her so much Trouble and Thought, are sometimes very inconvenient to us.

Inconvenient? replied the Marchioness. Is it not to these we are indebted for the beautiful Variety of the World? How tiresome and unpleasant would it be for us to see in all Objects a Repetition

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tition of the same Colour! You apprehend it, answered I, to be a great Evil always to see the World in *Chiaro oscuro*, if I may use that Expression, and to be obliged to be dressed always in the same Colour, and what is worse, in a Colour like that of your own Complexion. You may add, replied she, the Dread of losing a Topic of Discourse so very pleasing to Ladies.

All these Misfortunes, answered I, and this terrible Addition of yours would happen, if the Rays had no Disposition to separate from each other, or if they were all of the same Colour. The *Cameleon* and wrinkled Faces would be considerable Losers too. Some of these, without the Trouble of changing their Skin, are discovered in the Space of twelve, or at most twenty four Hours to change their Colours.

Astronomers on the other Hand would gain no small Advantage if the Rays were inseparable and of the same Colour. And what would not an Astronomer sacrifice to determine the exact Time of an Eclipse of *Jupiter's* Satellites,

lites, or to get a distinct Sight of the Occultation of a Star by the Moon? These are a Set of People whose Looks are always directed to Heaven, and have very little Regard for our Earth any farther than as she is a Planet, and upon that Account enters into the cælestial System. This is all they regard in her, and therefore would feel very little Concern if the Ladies of this Planet were under an Impossibility of changing every Day the Colour of their Cloaths, or subject to many other the like Inconveniencies.

But what Opposition, replied the Marchioness, can there be betwixt the Separability of the coloured Rays and the Observations of these Gentlemen, to make them quarrel with us for the Pleasure we receive from this Variety? There is a very great Opposition betwixt them, answered I, and you will be soon convinced of it, when I tell you that the Separability of the Rays is prejudicial to the Perfection of Telescopes, which Astronomers regard as their very Eyes. I before positively affirmed that

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Convex-Glasses, of which Telescopes are composed, unite the Rays, which proceeding from a Point, fall upon them into another Point. But the Truth is, I spoke rather with Regard to what they should do than what they really do. You seem, said the Marchioness, to have represented these Glasses in the same Light as tragic Writers do their Heroes; for these generally chuse to feign them what they ought to be, rather than imitate their Characters such as they really are.

It must be confessed, Madam, that I used a Sort of poetic Licence in telling you Convex-Glasses united the Rays into a Point, for it is not so truly a Point as a little Circle. This Circle, which is called the *Aberration* of the *Light*, proceeds from two Causes, the Figure commonly given to the Lens, and that Disposition which the Rays of Light have to separate themselves when they are refracted. But indeed the Figure of the Lens is but a very small Obstacle when compared to that of the different Refrangibility. All attempts therefore

to render Telescopes more perfect by giving a new Figure to the Lens, so as to make it unite the Rays truly in a Point, would be in vain.

In the Golden Age, of which the Poets give us so many fine Descriptions, when the Rivers flowed with Milk, and the Oaks distilled the fragrant Treasure of the Bee, when the Rams appeared in the Meadows arrayed in native Purple, and the Lamb displayed its vivid Scarlet to the Sun, before the Hand of Art had taught the Fleeces to imitate different Dies: In these happy Times, tis probable, the Telescope would have given a more distinct View of the Objects of Nature herself painted in their genuine and beauteous Colours, when the Heart of Man, animated with purer Passions, appeared without Disguise, and Love had not yet learned to sigh by Custom or Art, nor ever wept from any Motive but Joy. But in our Iron Age, in which both the Passions and Colours have degenerated from their original Purity, whatever be the Figure of the
Lens,

Lens, the Point where the blue or green Rays unite, will always be different from that of the yellow and red; there must always be an Aberration of the Light; and that little Circle will never become a Point. This is a Circumstance very inconvenient for Astronomers, whose Affairs require that every thing should be seen extremely distinct; but this Circle where the Rays unite instead of the Point where they ought to unite, or the different Refrangibility, which is the Cause of their uniting thus irregularly, is a great Obstacle to the obtaining the Exactness which Astronomers desire.

These accurate Gentlemen, said she, must have Patience, and pray for the Return of the Golden Age. In the mean Time they must limit their Desires and Wants as other reasonable Men do, and be contented with the different Refrangibility of the Rays instead of that very great Distinctness in Objects which they desire. It is not possible to have all Things at one Time in this World. Is the Knowledge of so

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many fine and surprizing Properties of Light so very small an Acquirement, that they cannot be satisfied without something more? Their Desires and their Wants however are so reasonable, said I, and have so great a Connexion with those of other People, that Sir *Isaac Newton* has thought upon a Method of satisfying them. With his own Hand he ground Glasses for Telescopes of a new Figure, in order to correct the Deficiency of ordinary Lenses. Then was the Time to have All, or hereafter hope for Nothing.

While his Mind was imployed in this Thought a new Scene of Optics opened to his View, he discovered the different Refrangibility of the Rays, laid aside the Work he had begun, and invented a new Telescope, in which a polished Minor supplies the Place of what in ordinary Telescopes is called the Object-Glass, and which had the greatest Share in the Aberration of Light.

I myself have seen the first Telescope of this Sort, worked by those Hands which had pointed to the Planets their
Road

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Road in the vast Desarts of a Vacuum, and opened to Geometry the immense Carrier of Infinity. This Instrument is preserved in a City of *England* where Philosophy and Politeness hold a mutual Empire; with this are treasured up those Prisms which the first Time differently refracted the Rays of Light in the Hands of our Great Philosopher, separated its Emeralds, Hyacinths and Rubies, and unfolded to human Eyes the celestial Riches of the lucid Robe of Day.

In the Reflection from a Mirror the Rays are not separated as they are in being refracted thro' a Lens, consequently the Objects may be much more distinctly seen.

It has been tried in *Italy* (for even among us Truth and Sir *Isaac Newton* have their Admirers) that if a distant Object, the one Half red and the other blue, be viewed with an ordinary Telescope, this Instrument must be considerably shortened to give a distinct Sight of the blue Half, and on the contrary must be lengthened to shew the

red distinctly; whereas in Sir *Isaac Newton's* Telescope they appear equally distinct with the same Length.

This reflecting Telescope has besides another Advantage over the ordinary ones, for one of Sir *Isaac's* Invention one Foot long is equivalent to one of twelve in the common Sort; and one of forty Foot, to a hundred. And this is another Convenience to Astronomers who find great Difficulty in managing long Telescopes.

It is well for us, replied the Marchioness, that these Astronomers will be now contented, for it seemed before a pretty difficult Matter to please them. How is it possible, answered I, for them not to be satisfied with Sir *Isaac Newton*, who seems in every Thing to have studied their Advantage?

His System of Optics (besides procuring them a more convenient and perfect Telescope) has vindicated the Honour of Astronomy from an Aspersion, which seemed in some Measure to disgrace it in the Eyes of the World. You are not ignorant that the Honour
of

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of this Science among Men consists principally in its exact Prediction of Eclipses and Events, no less observable to philosophical than to vulgar Eyes. *Thales* of *Miletus* was revered among the *Greeks* like a God for having predicted the Year in which an Eclipse of the Sun was to happen, that is, when the Moon would be interposed betwixt us and the Sun, and by that means deprive us of his Light.

As Astronomy successively became more perfect, what would have caused a Temple to be erected to a *Thales*, would only disgrace a *Hally*, *Cassini*, or a *Manfredi*.

The Observatory is required to shew the precise Minute in which the Eclipse will happen, and its exact Quantity, or in other Words, whether the Moon will observe the whole Sun or only a Part, and how much precisely the obscured Part will be.

Not long since all the Calculations of the most celebrated Astronomers had predicted two total Eclipses, whose principal Merit consists in not being
very

very common, and in introducing a sudden and unseasonable Night. An Event which tho' foretold and expected, never fails to terrify that whimsical Species of Animals called Man, that *Azy-lum* of the strongest Contradictions, nourished by long Hopes, impetuous Passions, the most evident Truth and the most palpable Error, capable of making Attempts beyond the Powers of his Nature, and subject to Fears which his Reason contradicts.

All the Philosophers got up very early on the Days appointed for this Spectacle, in order to prepare themselves for Observation. They all waited in the Midst of the Eclipse to see the Light of the Sun entirely extinguished, and a most gloomy and profound Night emerge from the Splendor of a fine Day. But the Event was contrary to their Expectations. There remained round the Moon a luminous Ring which made some falsely take them for annular Eclipses. When the Sun is nearest to the Earth, and the Moon at the greatest possible Distance, if there happens

happens in these Circumstances a Central Eclipse, as they call it, the Moon cannot hide all the Sun, but there remains all round its Edge a luminous Border resembling a Ring. But Astronomers gained nothing by this Explication, which was of no Signification in the present Case, and the World was but ill satisfied with Astronomy which is now believed an Impostor. The one murmured and were discontented, while the other racked their Brains to find the Reason of this Ring, which had the Confidence to appear in Spite of all their Calculations.

Some laid the Fault upon a luminous Atmosphere which incompasses the Sun, as our Air does the Earth, and became visible when the greater Light was obscured; others accused the Atmosphere of the Moon, which being illuminated at the Time of the Eclipse, appeared like a lucid Ring. But unhappily for them the first was innocent, and the second seemed so doubtful, that it might appear rather

rather a Mark of their Consternation, than an Explication of the Phænomenon.

I find myself greatly affected with Concern, said the Marchioness, for these unfortunate Astronomers abandoned by Heaven and Earth, and in the utmost Danger of losing their Reputation. It is however the Office of Humanity to have Compassion on the Afflicted. They must have Recourse, answered I, to the *Newtonian* Oracles if they would silence the Voice of Calumny. These were the Anchor of Hope in the present calamitous State of Affairs.

When the Rays of Light pass near the Extremity of a Body, they bend and incline towards the Body itself, and are thrown into its Shadow. If the Edge of a Knife be placed in a Ray of Light in a dark Chamber, the Rays which pass at some Distance from it, appear to bend and approach nearer its Back. *Grimaldo* was the first who observed this Quality which is called the *Diffraction* or *Inflection* of Light, and our Philosopher afterwards illustrated it

it with many new Experiments; and tho' he did a great deal, desired to do still more.

The solar Rays which pass near the Edges of the Moon must bend and cast themselves into the Shadow of the Moon herself. Observers then, who in the Time of an Eclipse are immersed in this Shadow, must receive these Rays bent from the Edges of the Moon, and see a luminous Ring round her, a Sort of Twilight resembling that which we see in the Evening and sometimes in the Morning, at the Horizon. The only Difference between our Twilight and this Ring is, that the first is occasioned by the Refraction which the Light suffers in coming from the Celestial Spaces into our Air, and the second by the *Diffraction* which it undergoes in passing near the Moon: But both are composed of Rays which do not seem destined by Nature for that Purpose.

To give a stronger Confirmation that this is the true Reason of this Ring, there have been made several Globes of artificial Moons, which exposed to the
Sun

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Sun and full Moon, have shown upon Earth the Effects of that Diffraction which had appeared so fatal to Astronomy in Heaven.

Astronomers, replied the Marchioness, have certainly great Reason to be satisfied with Sir *Isaac Newton* and his *Diffraction*, which has delivered them from such eminent Danger. But I must confess myself to be yet thoroughly discontented with it. Will you permit me to ask why those Rays which pass at some Distance from Bodies, must be inflected and bent? The Idea which this new Property of Light presents me with, is so very strange that I cannot conceive it. I find, answered I, you are more difficult to satisfy than the Astronomers themselves. You desire to know the Cause of this *Diffraction*. Well, I'll inform you, but you must promise not to draw back and frown when I tell you it is the Attraction which Bodies exercise upon Light. The Attraction! said the Marchioness with an Air of Surprise. You say this either to laugh at my Credulity, or punish my
too

too presumptuous Curiosity. What, do Bodies attract the Light as a Loadstone does Iron? What ill Consequences would arise supposing it were so? answered I, Or rather how great an Advantage has the Science of Optics in particular gained from this Attraction between Light and Bodies, as all Natural Philosophy in general has from the universal Attraction of Matter, of which that between Bodies and Light is a Consequence?

Attraction is the Key of all Philosophy, the great Spring that actuates the Frame of Nature; the universal and mysterious Force discovered and calculated by Sir *Isaac Newton*, proposed to the Examination of Philosophers by the great Lord *Bacon*, and obscurely sung by the *British Homer*.

The Marchioness recollected herself, and looked very attentively in my Face to see whether I spoke in Earnest. Do you tell me seriously, she replied, that all Bodies are attracted? This is quite a new World to me when I am an utter Stranger and Foreigner. Do not be
dis-

discouraged, said I, for this has happened to many professed Philosophers who have exclaimed against this Attraction, affirming, that to admit it is introducing into Philosophy certain occult Qualities which the Ancients supposed in Bodies, such as Sympathy, Antipathy and the like, whose Numbers multiplied with the Phænomena themselves, by the Assistance of which they in an Instant explained, or rather perplexed every Thing.

They farther add, that it is recalling those occult Qualities from those Colleges of *Europe*, where Ignorance still affords them an Asylum to introduce them into true Philosophy, from whence they for the Happiness of Mankind had been banished by the Authority of Reason.

But all these Objections signify nothing, for Attraction is so far from being an *occult*, that it is an extremely *evident* Quality of Matter, on which clearly depends the Explication of *Diffracti*on, Refraction itself, and innumerable other Things. It is not a Name without Reality, invented to explain

two

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two or three Appearances, but a general Principle diffused thro' all Nature, and extends from the smallest Grain of Sand to the greatest Planet. The *Peripatetics* resembled those Ancients, who for every little River or Tree, nay even for the Fever or the Cholic, created a new Deity. But Sir *Isaac Newton* appears as a great Philosopher, who by the Help of Attraction establishes the Existence of an all-powerful, infinite and only God, the Supreme Director of the whole Frame of Nature.

Sir *Isaac Newton* (when he affirms that Light in passing near the Extremity of Bodies is attracted by them, does not pretend by that to give a compleat Explication of *Diffraction*; all he undertakes is only to point out that Property of Matter on which the Explication of *Diffraction* depends, but the Cause of this Property is to seek. This he commits to those Philosophers who have superfluous Time enough to throw away in Search of a Thing which appears above the Reach of human Faculties. In short, all that Sir
Isaac

Isaac Newton attempts is to establish Facts and the general Properties of Matter, and from these geometrically to deduce Phænomena and Effects; and this is the Order we have hitherto observed in our Discourse upon Light and Colours.

This new Property, replied the Marchioness, is of a Nature which my Thoughts cannot so easily come into. This is one of those historical Facts of which it is impossible to get a perfect Intelligence without entering into the Cabinet. I understand, or think I understand, how the Rays of Light are differently refrangible. This, among many other Things, is very intelligible. But that Bodies should attract the Light, and that at a certain Distance too, and in general that every thing should be mutually attracted, seems to me very difficult to conceive.

Some Remains of *Cartesianism*, answered I, which you are not yet entirely free from, deceives you in this Point. Perhaps you have hitherto flattered
your-

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yourself that Refraction arises from some one of those Causes which in treating upon the *Cartesian* System were rendered so familiar to you, and upon this Account you think Refraction more intelligible than *Diffraction*. Sir *Isaac Newton* himself appears in some Places to have indulged the Prejudices of this Sect. In order to speak the Language then current in Philosophy, he said, that Attraction perhaps might be the Impulse of a subtile Matter proceeding from Bodies. But in Fact after he had proved the Heavens to be empty, and the Celestial Bodies mutually attracted in those vast Spaces, what Room did there remain for the Impulse and subtile Matter? He seems to resemble certain Authors, who, to make their History agreeable to any particular Nation, are sometimes obliged to intersperse it with fabulous Episodes, and give it the Air of a Romance. Is it not a great Reproach upon Mankind that even the Truths of Sir *Isaac Newton* were obliged to use some little Artifice in

in order to meet with a Reception among them?

Is not this rather an Artifice of yours, interrupted the Marchioness, to surprize me by a Motive of Honour, and in this Manner make me believe that I have no better Conception of the subtile Matter than of Attractions, or how Bodies should be indued with Motion, for Example, than with that which you rightly term a *mysterious* Force?

Your Illusion, answered I, proceeds from hence, that you are familiarized to one Idea and not to the other. You every Day see Bodies move and mutually communicate their Motion, but you have never seen them *attract* each other. You are surprized at Attraction while Motion appears to have no Difficulty. In this you differ from Philosophers who like Poets for the Solution of any difficult Point are obliged to have Recourse to the Divinity for the Explications both of Motion and its Communication.

A *Portuguese* accustomed to reverence Spectacles upon the Nose of the gravest

graveſt Perſons as a Mark of the greateſt Dignity, would probably be ſurprized to ſee a *Chineſe* Mandarin let his Nails grow to an enormous Length for the very ſame Reaſon. And the Cauſe of his being ſurprized in one Caſe and not in the other is, that a long Habit has connected in his Mind the two Ideas of Honour and Spectacles which have nothing in common with each other, but has not connected thoſe of Honour and long Nails. I ſhall at leaſt deſerve more Compaſſion than the *Portugueſe*, replied the Marchionefs, becauſe the Surprize of ſeeing Matter united to Attraction inſtead of Motion will I believe be common to all Countries.

As univerſal and excuſable as this Surprize may be, I answered, it muſt however at laſt ſubmit to Reaſon. If you had never ſeen Bodies move it would have been impoſſible for you to gueſs how Motion would be joined with Extenſion and mutual Impenetrability, which would be all the Qualities you would then have been acquainted with. It is Obſervation which has made you admit

admit this Property in Matter, and Observation must make you allow Attraction. We are as yet but Children in this vast Universe, and are very far from having a compleat Idea of Matter; we are utterly unable to pronounce what Properties are agreeable to it, and what are not. We see Bodies in very near the same Manner as a Person, who should receive his Senses by little and little. It would certainly be great Temerity in him to affirm that there cannot be a Property in Matter capable of moving the Eye, and should assign as a Reason for this Assertion, that he had never been able to observe any such Property.

This Person would not act like the *Cartesians* who form a World and a Man just as their own Caprice directed them; he would grow more cautious in limiting the Power of Nature and pronouncing the Qualities of Bodies, in Proportion as he should acquire new Senses, which would every Day furnish him with fresh Discoveries of these Things.

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Philosophers may be said in some Degree to acquire new Senses, or rather those they before had become every Day more refined, and are by that Means in a Capacity of perceiving what perhaps they had once no Idea of. Hence it evidently follows, how very cautiously they ought to proceed in assigning the Number of Properties in Matter. It signifies nothing to say that some are more intelligible than others, for to speak ingenuously, they are all equally mysterious to us.

Will you any longer make a Difficulty, Madam, to admit Attraction as a Property of Matter when it is proved so many Ways, and principally by the heavenly Phænomena, which give the most shining Testimony to a Thing that you yourself so evidently demonstrate the Truth of? I assure you for my Part I shall never look for any farther Demonstration of it than what you afford.

But I, replied the Marchioness, shall not be so easily satisfied, for I have need of the daily Attestation of all Heaven

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itself

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itself to convince me of a Thing which yet appears so strange and surprising. It is absolutely needful then, continued I, to give you a full Conviction of it. And indeed it would be doing a great Injury both to Sir *Isaac Newton* and yourself, to endeavour to make you believe a Thing without giving you good Reasons. I am sorry this System cannot be explained to you with all the Force of those Demonstrations and Calculations which accompany it; without these you must certainly lose a great deal. I will have Patience, said she; if I cannot see it in all that Lustre in which it would appear to a Mathematician, and will act like those Virtuosi, who when they cannot get a Picture content themselves with the Copy of it. I flatter myself you will render it as like the Original as possible. It is at present too late, I replied, for this Expedition. To-morrow we will ascend into Heaven, and from thence bring Attraction down in Triumph to Earth. Some Astronomical Facts and Propositions in Geometry, which you may
safely

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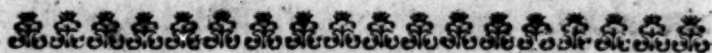
safely believe upon the Word of Sir
Isaac Newton, shall serve for a Hippo-
gryph, or flying Car, to transport us to
the Skies.



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The

The SIXTH DIALOGUE.



Exposition of the Newtonian universal Principle of Attraction, and Application of this Principle to Optics.

CONCLUSION.

THE next Morning the Marchioness no less impatient for Attraction than she had been for all the rest, after a few short Compliments, began, It is now Time to mount our Hippogryph, and give him the Reins. He will not grow weary, answered I, for a little Journey, if I can remember certain horrible Numbers.

All the Planets revolve at various Distances round the Sun, who is almost nine hundred thousand Times bigger than the Earth, and forms the Centre of their Motion, while he remains in the

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the Tranquillity of a Majestic Repose. Nearest the Sun, at a Distance however of thirty two Millions of *English* Miles, is the little World of *Mercury*, then follows the lucid Orb of *Venus* fifty nine Millions distant, then our Earth eighty one, *Mars* at one hundred and twenty three, the enormous Bulk of *Jupiter* four hundred and twenty four, and the vast and slow-moving *Saturn*, seven hundred and seventy seven Millions of Miles.

These all preserve this natural Order in their Motions, that those nearest the Sun compleat their Revolution or Orbit in a shorter Time, and the most distant in a longer: Thus *Mercury* finishes his Revolution in eighty eight Days, *Venus* in two hundred and twenty four and some Hours, the Earth, as you already know, in a Year, *Mars* in about two Years, *Jupiter* in almost twelve, and *Saturn* in about twenty nine Years and a Half.

There is so great a Dependance and Relation between the periodical Revolutions of the Planets and their Distan-

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ces from the Sun, that if we know the Distances of any two (of the Earth and *Jupiter* for Instance) and the periodical Time of one, (suppose of the Earth) by a certain Rule we may find the periodical Time of the other.

I should have a much clearer Idea of your Meaning, said the Marchioness, if I had first read *Fontenelle's* Plurality of Worlds to convince me of the Motion and Agility of the Earth. As you are now so great a Proficient in Philosophy, I replied, you must seek the true Demonstration of this Motion in *England*.

There have been observed certain Appearances in the Stars which some imagined to be Consequences of this Motion, but others who examined it more strictly, have discovered these Appearances to be contrary to the Laws of such a Motion. The Motion of Light which is a considerable Time in coming from the Stars to us must strangely vary their Appearances, and ought to be considered in Conjunction with the Earth's Motion round the Sun, in order
to

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to give a right Decision of the Question.

The Sagacity of the *English* Philosophers has in Fact united these two Motions, and by this Means they explain these surprizing and various Appearances which in any other System are absolutely inexplicable. And thus we have attained to the Certainty of a Thing proved a thousand Ways, but never strictly demonstrated by any.

The five Planets in whose Number we may safely replace our Earth, are called *Primary*, to distinguish them from other subaltern Planets which revolve round a Primary as the Moon does round our Earth, the four Satellites of *Jupiter* round that Planet, and five round *Saturn*; and these Sabalterns are called *Secondaries*. These last agree with their Primaries in observing this Order, that the nearest compleat their Orbit in a less, and the most distant in a greater Time; and they keep this Law with the same Exactness and the same Relation as their Primaries do.

Another Law in which the primary and secondary Planets agree is, that they

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do not describe equal Parts of Orbits in equal Times, but such Parts of Orbits as to make their Areas equal. That you may better understand this other Law of their Motion, you are to suppose that the Orbit of a primary Planet is very near a Circle which the Sun is not placed directly in the Center of, but a little on one Side. Imagine a Line to be drawn from that Point of the Orbit where the Planet now is, to the Sun, and another Line to be drawn from that Point where the Planet will be twenty four Hours hence. The Space contained betwixt the two Lines drawn to the Sun, and that Part of the Orbit which the Planet has described in twenty four Hours, is called the *Area*, and will be equal to another such Area, that the Planet will describe in twenty four Hours more; and thus in equal Times the Areas will be always equal.

The *Areas* then, as Astronomers express it, are *proportional to the Times*. Thus if instead of twenty four Hours we put twelve, which is one Half, an Area described in those twelve Hours will be
only

only one Half of the Area described in the 24; and so, if we take a third or fourth part of the Time, the Areas described in that third or fourth Part, will be the third or fourth of those described in the first Time; and if that Time be doubled, the Area described in it will be doubled likewise, and so on. This Law which the primary Planets observe with Regard to the Sun, the secondary Planets observe with Regard to the Primary, round which they revolve; and this Primary is the same to its Satellites, as the Sun is to the Planets of the first Order.

I am extremely pleased, said the Marchioness, with the Agreement between these two Sorts of Planets. I regard the Sun as Monarch of the immense planetary Realm, in which the primary Planets are the Grandees and Nobles; some of these possess certain Districts where they exercise the same Jurisdiction in little which their Sovereign does in great, but all shew their Dependence by revolving round him alone.

Our Earth is in Possession of a little Province, where she exacts Obedience

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from the Moon; and tho' she cannot vie with *Jupiter* or *Saturn* who have a greater Number of Dependants, she is certainly superior to *Mars*, *Mercury* and *Venus*, who have none.

Your Similitude, answered I, would be juster in the *Cartesian* System of Vortices where these Jurisdictions seem very well established; and it would be the more so, because this philosophical Poetry is fond of imbellishing itself with Comparisons and Similies, and sometimes makes them even serve for Reasons. But the two Laws I have mentioned to you, will not suffer it. Indeed it is Pity we are obliged to abandon these Vortices, that present the Mind with so clear, so natural and simple an Idea. The Planets, say the *Cartesians*, revolve round the Sun, because a certain Fluid in which they are immersed turns round too, and carries them with it like little Skiffs forced along by the Current of a River. The secondary Planets revolve round their Primaries for the same Reason.

Nothing seems to be more evident than this. But the Misfortune is that these

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these Planets are not contented with barely turning round, but will do it by certain inviolable Laws that intirely destroy all these imaginary Systems.

Either these two Laws cannot agree with the Vortices, or agree so ill, notwithstanding all the Efforts to that Purpose, that one of their most illustrious Defenders confesses, after all he has done in their Support, he doubted whether those who refuse to admit them would not be confirmed in their Opinion by the very Manner in which he has endeavoured to defeat it. Besides these Vortices are pressed by so many other insuperable Difficulties, that Heaven itself seems to have conspired in the Destruction of this fine Poem.

Far be it from us, replied the Marchioness, to oppose the Decrees of Heaven. On the other Hand, I cannot reconcile myself to the Idea of a Poem in Philosophy. What is this philosophical Poetry to which I cannot assign a Place in my Thoughts? It ought to content itself with influencing the Passions of *Men*, but it has nothing to do with the single Passion of *Philosophers*, which is Truth. The

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The *Newtonian* Principles, answered I, have inspired you with very rigid Sentiments. But this Poetry, that thinks itself too much limited in the vast Field of human Passions, shall give you no further Trouble. Comets, the most declared Enemies in all Heaven to their Vortices, will I believe be sufficient to overthrow it, for they seem to be made expressly for the Destruction of Systems.

It has been established, by Virtue of I know not what, but however the Philosophers have very readily believed, that the Matter of the Heavens was incorruptible, and that every thing there flourished in a perpetual Youth, insusceptible of the Changes and Vicissitudes which happen here below. The Comets appear at first almost naked, but in their Approach to the Sun are cloathed with a formidable Tail, of which they gradually divest themselves as they recede from him, and so return back naked as they came. And in this Manner is the System of the Incorruptibility of Heavenly Regions, in great Danger of being overthrown by these impertinent Comets. And this perhaps

is the Reason why they were degraded from their Celestial Seat as worthless Meteors formed by the Vapours and Exhalations of our lower World. But they would not remain long there; for besides many ancient Philosophers who considered them not as one of the transient, but durable Works of Nature, the Astronomers who must have their Share in a Thing above us, assure us, that they are very distant from the Earth, and some of them farther off than the Sun himself. These Comets, said the Marchioness, are very bad Omens to Systems, if not to crowned Heads. These were not all the Troubles, said I, which they gave Philosophers. When they were placed among the celestial Bodies, they could not agree with that Solidity which had been granted to the Heavens upon the Word of *Aristotle*; in order therefore to avoid their demolishing and breaking to Pieces the whole Universe in their Passage through these *Aristotelian* Heavens, it was necessary to resolve upon making these last fluid.

When the Heavens were thus made fluid they became Vortices, against
which

which these factious Comets renewed their Enmity with more Violence than ever, to destroy an agreeable Imagination received by the World with so much Applause, and which was defective in nothing but Truth.

Some Comets have made no Difficulty to cross the Orbits of all the Planets, proceeding almost directly from the superior Part of the Vortex to the Sun; others have moved in a Course absolutely contrary to that of the Planets, without meeting either in the first or second Case, any Resistance in their Motion, which must necessarily have happened, if there was a certain Matter that whirl'd round the Sun, and this at several Distances from him with the same Rapidity as the Planets supposed to swim in those Vortices. Their Motion would have been so weakened, that turning round the same Way as the Planets do, they would soon have yielded to the irresistible Force of the Vortices, not unlike the unfortunate Barks, which guided by an unskilful Pilot or a malignant Star, are Ship-wreck'd in the horrible Cataracts.

raets of the *Chinese* Rivers, notwithstanding all the struggling they can make to the contrary.

In short, these Comets have in every Instance acted directly opposite to the Laws of Vortices. So that to rescue them from the continual Injuries they receive from these implacable Enemies which lay hold on every Occasion to commit all Sorts of Hostility and Impertinence, I see no other Remedy than to destroy and banish these unhappy Fluids for ever from the System of the World.

Your Expedient, replied the Marchioness, is no less violent than that sometimes used in War, when one Party destroy and ruin a Country which they cannot defend against the Enemy. And thus they make the same Sacrifice to their Weakness as you do to Truth. This is a Sacrifice at which I cannot be displeased, especially as it puts me into a better Capacity of listening with more Tranquillity to the new Principle upon which the celestial System is built.

Sir *Isaac Newton*, continued I, founded his Scheme in Geometry, which we
may

may call his native Country. He began with demonstrating that if a Body in Motion is attracted towards a Point either moveable or immoveable, it will describe about this Point equal Areas in equal Times, and in general, that the Areas will be proportional to the Times; and on the contrary, if a Body describes round a moveable or immoveable Point Areas proportional to the Times, it will be attracted towards that Point, that is, the Body will have such a Tendency towards the Point, that if every other Motion which impels it a different Way should cease, the Body would directly unite itself to that Point, just as Bodies here below, when left to themselves, fall directly upon the Earth.

This Principle, interrupted the Marchioness, is equally applicable both to the primary and secondary Planets. Each of these describe Areas proportional to the Times, round the Point about which they turn (if the Sun, our Earth and *Jupiter* may be termed Points). The primary Planets then are attracted by the Sun, and the secondary
by

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by their respective Primaries about which they revolve. Is not this a necessary Consequence? It is without Dispute absolutely necessary, answered I. But remember, Madam, this is a Deduction of your own. This Punishment is just, since you have made so much Difficulty to admit the Principle of Attraction.

You say then that there is a Force in the Sun which attracts the Planets to him, and after the same Manner, a Force in the Planets that attracts the Satellites, and this attractive Force joined with another by which they all move from West to East, is the Reason why the first revolve round the Sun, and the others round their Primaries, in a certain Order.

The Ancients, in order to explain this difficult Phænomenon, built solid Heavens and created Intelligences to put them in Motion; on the other Hand, *Des Cartes* had imbarassed the whole Universe with the great and magnificent Apparatus of his Vortices. But after all, the Motion of the heavenly Bodies is by Sir *Isaac Newton* reduced to the most simple yet the most noble Phæ-

Phænomenon in the World, which has been rendered much more familiar in *Europe*, than is agreeable to some Persons. In short it is no more than that of a Bullet, which would of itself proceed in a direct Line, if the attractive Force of the Earth did not oblige it to move in a Curve. The Bullet very soon falls to the Earth, because the greatest Force we can possibly give it, is but little when compared to the vast Extent of this Globe. If it were possible for human Weakness to throw one from hence beyond *Peru*, it is demonstrated that we should acquire a new Satellite; it would like the Moon revolve about our Earth, only its Motion being necessarily very soon weakened from the continual Resistance of the Air, while the gravitating Force would lose nothing of its Strength, this new Moon would at last fall and destroy every thing it lighted on, after we had heard it make a horrible hissing over our Heads.

All this you explain in two Sentences; an evident Proof of the Significancy of

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a Lady's Words. What you have said is certainly a great deal, but not all. It still remains to know by what Law this attractive Force acts, that is, whether it be the same at all Distances from the Sun, or whether it grows weaker in Proportion as the Distance is greater. I will resolve you this Question, the Marchioness replied, when you have furnished me with as many Hints for that Purpose as you did when I told you that the Planets are attracted by the Sun; and I hope you will afterwards make as genteel a Commentary upon me as you did in the other Case.

That Law, answered I, of describing Areas proportional to the Times observed by every particular Planet, furnished Sir *Isaac Newton* with Means to discover the attractive Force of the Sun; and that other Law which they observe, of describing their Orbits in a greater Time in Proportion as they are at a greater Distance from the Sun, and that with a certain Relation between these Times and their Distances, helped him to find out that the attractive Force diminishes

minishes as the Distance from the Sun increases.

The attractive Force diminishes with this Proportion, that it is always so much less as the Square of the Number which expresses the Distance from the Sun is greater. In order to understand this Cyphering (which perhaps at first Sight may appear very formidable) it is necessary to acquaint you that the *Square* of any Number is nothing but that same Number multiplied by itself, as *four* for Instance is the Square of *two*, because *twice two* makes *four*, that is, *two* multiplied by itself gives *four*.

I may now safely venture to propose you a Problem, that as you have lately explained the Phænomena of Natural Philosophy, you may now undertake the Solution of mathematical Problems: After this I do not see what you can do better than to shew some Sort of Gratitude, and discover the Truth to him who has conducted you into its most abstruse and retired Paths.

The Problem I shall propose to you is this: Suppose the Earth's Distance
from

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from the Sun to be *one*, and *Jupiter's* Distance from him to be about *five*, (considered with Respect to that of the Earth,) the Question is to know how much the Sun's attractive Force will be diminished at the Distance of *Jupiter*?

Give me a little Time to consider, answered she with some Impatience, for the Solution of a Problem is no trifling Affair. You have informed me that the attractive Force is so much less, as the Square of that Number which expresses the Distance is greater. The Square of *one* which is the Earth's Distance from the Sun, is *one*. And at the distance *one*, answered I, the Force is supposed to be *one*, and the Question you are to resolve is, How much that Force will be diminished at the Distance of *Jupiter* from the Sun which is *five*. The Square of *five*, answered she with great Quickness, is *twenty five*. If the attractive Force must be so much less as this Square is greater, it follows that in *Jupiter* it is twenty five times less than in the Earth. Is not this the Solution of your Problem? and may not I, like *Archimedes*,

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chimedes, run crying about, *I have found it, I have found it?*

Yes certainly, answered I, but not in the same Circumstance as he did, when his Impatience was so great as to make him run precipitately out of the Bath. The Mathematicians ought rather to act as *Pythagoras* did upon the Discovery of a certain Truth, and sacrifice a Hecatomb to solemnize this Day which gives them Liberty to imbellish and brighten their gloomy Catalogue by your Name.

The Law that the attractive Force observes of growing weaker at various Distances from the Sun, is the very same to which all other Qualities that flow from Bodies, are subject; as Smell, Sound, Heat, and, which most nearly concerns us, Light. Thus when you believe yourself to have solved only one Problem, you have in reality solved two. Is then, replied she, the Light of the Sun as well as his Attraction twenty five times less in *Jupiter* than with us? The very same Number, answered I, serves equally for both. After the same
Manner

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Manner you will find that the Attraction, the Light and Heat of the Sun, must be ninety times less in *Saturn* than with us. The Twilight of our farthest *Laplanders* would be there the finest Summer Days, and in the most raging Dog-star of that Planet our Seas hardened with perpetual Ice, instead of swift sailing Vessels, would groan under the Weight of heavy Chariots; whereas in *Mercury* they would even in the Depth of Winter be dissipated into thin Vapors (occasioned by his extreme Proximity to the Sun) and would thus leave their Bottom dry, and present to Pilots a horrid Gulf, a dreadful View of the Terrors of the Deep; and to Naturalists a beautiful Scene that would furnish them Materials to enrich their Musæums.

You see, answered she smiling, how many fine Discoveries I have made without perceiving any thing of it. It is however true, that great Affairs are generally brought to pass we know not how, and we are at last amazed to find them effected.

In human Affairs, answered I, it is ascribed

ascribed to their good Fortune, if the *Cæsars* and *Alexanders* after proposing only one End, acquire another which they never dream'd on. It often happens, that those very Persons who are called fortunate gain that Name by some Events very different from what they intended. The Inventer of Gunpowder, 'tis probable, proposed a quite different End to his Studies than the Discovery of a Secret to destroy Mankind with the greater Facility; and that Person who found a new World sought nothing but a more expeditious Way to the richest Part of the old.

On the other Hand, in true Natural Philosophy and Geometry, the *Cæsars* and *Alexanders* are more common. It is very seldom that we find only what we sought. The Discovery of one Truth frequently produces many others which appear in Spite, as it were, of those who seemed to disregard them. Any one who carefully seeks that Law by which the attractive Force ought to act at various Distances, will at the same Time discover that universal Law by which

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which all the Qualities which flow from Bodies are governed. Natural Philosophy afterwards illustrates this general Truth with peculiar Experiments, and in some measure translates the abstruse Hieroglyphics of the learned Tongue into vulgar Language. That Decrease of the attractive Force which immediately concerns Light, is demonstrated by a very easy Experiment, which we may try this Evening, if you are not already sufficiently tired with Philosophy and Experiments.

Suppose one single Candle to be placed in a Room, and recede from it to such a Distance as not to be able to distinguish the Characters of a Book or a Letter, unless perhaps it were a Billet-doux, which may be read at any Distance.

Place yourself afterwards at a Distance twice as far from the Candle as you were at first. In this Situation the Force of the Light must be, according to the established Law, four times less than it was at the first Distance. The Letter then cannot be read with the
I same

same Distinctness as it was at first, unless the Light be *quadrupled*: That is, the Law requires that in the Proportion as the Light grows weaker, the Square of the Distance must increase. And this proves the Experiment to be true; for the Letter at the second Distance is then only read with the same Distinctness as at the first, when three more Candles are added to the single one, or, in other Words, when the Light is *quadrupled*.

Considering how very easily People are apt to forget those Objects in their Absence which made the greatest Impressions upon their Mind when present, I cannot help thinking, said the Marchioness, that this Proportion in the Squares of the Distances of Places, or rather of Times, is observed even in Love. Thus after eight Days Absence Love becomes sixty four times less than it was the first Day, and according to this Proportion it must soon be entirely obliterated; I fancy there will be found, especially in the present Age, very few Experiments to the contrary. I believe, said I, that both Sexes are included in this

Theorem,

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Theorem, which seems rather to follow the Cubes of the Times, which is certainly more convenient, and requires only four Days for an intire Oblivion. But, in general, I believe we may without Scruple establish the Proportion of the Squares, for eight Days are commonly enough to cure the most vehement Passion. You alone have Power to reverse this Theorem, and make the Remembrance of you, and with that, a Desire of seeing you, instead of diminishing, increase according to the Squares, or rather the Cubes of the Times. No! no! said the Marchioness, Gallantry must never destroy a Theorem. I am willing to enter into the general Rule, and shall think myself exceedingly happy if I have been able to establish any thing fixed and constant, in an Affair so inconsistent and wavering as Love. If Geometry, answered I, was permitted to get some Footing there, it would in a little Time produce Wonders. The Conclusions would be the most ready and elegant imaginable.

But to be serious, said she: Our Conclusion

clusion in Natural Philosophy was, That the attractive Force of the Sun diminishes in Proportion as the Squares of the Distances increase. I suppose the attractive Force of the Planets will follow the same Proportion with Regard to their Satellites. The Satellites, answered I, which turn about any Planet, observe the same Relation between the Distances and the Times of their Revolutions, as the Planets themselves do that turn about the Sun. This is evident in *Jupiter* and *Saturn*, who have more than one Satellite, and consequently the Law of their attractive Force will be the same as that of the Sun.

In the Earth, who has only one single Satellite to her Share, this is not altogether so evident. But what Reason is there why it should not be the same in one as in the other?

If we had another Satellite revolving about our Earth at a Distance different from that of the Moon, it would discover whether the attractive Force of the Earth observes the same Law as that of the Sun *Jupiter* and *Saturn*. This Defect

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Defect however is supplied by the Bodies which we see every Day fall upon the Surface of the Earth; for we are to believe that the Force which would make the Moon fall if she lost her Motion from West to East, is the very same that makes Bodies here below fall upon the Surface of the Earth when they are left to themselves: For since it is demonstrated that the Earth has an attractive Force, it is evident we must in this Force seek the Cause of Gravity, another Phenomenon, which the Vortices have been as unsuccessful in the Explication of, as in that of the planetary Motions.

If we could raise Bodies from the Earth to very considerable Distances (compared with that at which we stand from the Center which is very great,) we should see the Force of Gravity prodigiously diminished in them. A Man of War of a hundred Guns, for whose Formation a whole Forest was cut down, and a whole Mine exhausted, would be overset by the slightest Breeze of a Zephyr. The famous *Stone-Henge*

I 3 upon

upon *Salisbury* Plain, the fruitful Source of Fables both to the Learned and Ignorant, those *Colossian* Heaps which are held together by the Force of Gravity, would be no more than Houses built of Card. The Velocity in the Fall of heavy Bodies would be considerably retarded. Bombs, those artificial Thunders, would not be more terrible than so many Flakes of Snow. But these Experiments are impracticable; one of the greatest Distances we can attain is *Pike Teneriff*, which is only about three Miles perpendicularly high. Besides the Air would be too thin for Respiration, and the Cold, which must be exceedingly sharp at a greater Height, would render any Experiment fatal to the Philosopher who had the Courage to undertake it.

Nature, replied the Marchioness, has in this Case denied us the Means of being compleat *Newtonians*. She has here confined us within the Bounds of Probability. If the attractive Force observes a certain Law in the Sun, *Jupiter* and *Saturn*, why should not the same Force
observe

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observe it here on our Earth? In this Point, answered I, we have no Reason to complain; we have no Need of higher Mountains, and a different Constitution of Air, in the present Case. All these Things, and the Defect of another Moon, are, as I before observed, supplied by the Bodies which fall upon the Surface of the Earth. We may compare these Bodies to the Moon herself; and thus instead of Probability we shall have Evidence, and be even in this Point, good *Newtonians*.

It has been deduced from Observation, that if the Moon should lose her Motion, and fall towards the Earth, that Force which would set her a falling would be three thousand six hundred times less than the Force which makes Bodies fall upon the Surface of the Earth. You see how well this agrees with our Principle. The Moon is distant from the Center of the Earth (where the attractive Force chiefly resides) sixty times as far as these Bodies: The Square of sixty is 3600: The Attraction then of the Earth to the Moon is diminished in the same Proportion

tion as the Square of the Distance is increased; and this is exactly agreeable to the established Law in *Jupiter*, *Saturn*, and the *Sun*.

If the Moon should happen to fall upon the Earth, replied the Marchioness, it would present a fine and agreeable Sight to the *Newtonians*: They would certainly have neither Curiosity, Eyes, nor Calculations for any thing else. This might very easily happen, answered I, if every thing was Body, as the *Cartesians* affirm; and those ancient *Gauls*, who were apprehensive the Heavens might one Day or other fall upon their Heads, would have some Reason to fear it in the System of their own *Des Cartes*: For it has been demonstrated that if this Planet was to move in a Place absolutely filled with Matter, without the least empty Space (let this Matter be supposed ever so subtile, fluid and æthereal) her Motion from West to East would be so retarded that it would soon grow weaker, and at length totally fail. And thus yielding to the Force of Gravity she would fall precipitately from
Heaven

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Heaven to Earth, and we should no more behold her that *triform* Goddess we before admired, but a Stranger banished from the most shining of her three Kingdoms, and no longer the Ornament of Heaven amidst the friendly Silence of the Night.

The other Planets would undergo the same Fate if they moved in a Plenum. These would all, some sooner and others later, fall into the Sun, and supply that immense Volcano with a greater Quantity of Matter. He would then reign the Sovereign of a depopulated Empire: His animating Light would shine in vain: Not a single Planet would be left to partake his pleasing Influence, nor receive from him the Seasons and the Day; for both the Comets and we with our Moon should be stifled in him, if we met with any Obstacle in our æthereal Road. This would be a new Punishment to an Age fruitful of Crimes, in the System of that *English* Writer (*)

(*) Mr. *Swinden* in his *Treatise of the Nature and Place of Hell*.

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who makes the glorious Body of the Sun the Mansion of Grief, and the Seat of eternal Despair.

I assure you, for my part, I should be one of the first, continued I, who would run to see the Moon fall upon the Earth. What an agreeable Spectacle would it be to see, in Proportion as she approached to us, that Face, that Mouth and Nose, which we discover in her rather by our Imagination than our Eyes, gradually transformed into great Mountains, Vallies, Plains and the like, which must certainly fill the Vulgar with great Astonishment: Nay even Philosophers themselves, who can never sufficiently master those two great Enemies of Reason, Fancy and Prejudice, could not help looking on this Phenomenon without some Degree of Surprise. As she approached still nearer, said the Marchioness, should not we descry the Sighs of Lovers, Dedications to Princes, Courtiers Promises, Vitals filled with the Judgment of our Sages, and all the other lost Things which *Ariosto* places there? You have not

not read the Plurality of Worlds, answered I, and therefore are not capable of seeing the greatest Curiosities in that Planet; since you are not yet acquainted with the Force of a *Why not*, which peoples the whole Universe.

But one Thing which I should take great Pleasure in observing, if the Moon should really happen to fall, is, what Treatment the Earth would give the Moon in going to receive her.

What, replied the Marchioness, is it a Point of Ceremony established among the Planets, that if a Satellite should fall upon its Primary, the latter must go meet it and shorten its Way? This Ceremony, answered I, is founded upon mutual and reciprocal Attraction. If the Earth attracts the Moon, why should not the Moon attract the Earth? The Attraction which the Earth exercises upon the Moon is lodged in that Matter of which the Earth is composed, why then should not the Matter of which the Moon is composed exercise its attractive Force upon the Earth, since all Matter is entirely the same, and
only

only differently modified in different Bodies? Besides *Action*, as the Philosophers express it, *is always equal to Reaction*. You cannot press this Table with your Finger, but it will be equally re-pressed by the Table. Thus if two little Gondolas made of Cork (in one of which is placed a Loadstone, and in the other a Piece of Iron) are set a floating upon the Water near each other, the Loadstone will run as fast towards the Iron as the Iron does towards the Loadstone; and if either of them be hindered, that left at Liberty will spring towards the other, which could not happen unless the Iron attracted the Loadstone as much as the Loadstone itself does the Iron, or, in short, unless their Attraction were reciprocal.

I perceive, said the Marchioness, what will be the Conclusion of all this. The Sun attracts the Planets, and consequently the Planets attract the Sun: The Secondaries attract each other, are all attracted by the Sun, and all attract him. Does not this Multiplicity, this
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Chaos

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Chaos of Attractions perplex not only me but the System itself too? No, Madam, answered I, it happens in this just as in the new Geometry (of which I was speaking to you the other Day) in which all those innumerable Orders of infinitely small Quantities, instead of perplexing, render it more subtle and perfect.

This mutual Attraction, diffused through the Universe and all its Parts, retains the wandering Planets in their Orbits, and connects all Bodies, the Earth, and us ourselves, by strong tho' invifible Ties, and regulates and tempers every Motion in fuch a Manner, that its Exiftence and inrefiftible Laws are every Instant apparent.

In thinking on this reciprocal Attraction, faid the Marchionefs, fomething comes into my Mind, which I dare not however propofe as an Objection to a System which the Philofophers themfelves cannot venture to oppofe. It appears to me that if there really was fuch a mutual Attraction, we muft fee the Effects of it in thofe Bodies

Bodies which surround us, if not every Instant, at least very often, just as we discover from their Gravity the Effects of that general Attraction which the Earth exercises upon them.

When any little light Body, as a Feather for Instance, be placed near a Palace, a Hill, or any Thing whose Attraction is very strong, why do not we see it presently obey the Force which attracts it, and move, as it should do, towards the Palace or Hill? When our Mind is possessed by a very strong Passion, answered I, what is the Reason we do not feel the weaker, unless it be that the strong Passion attracts the whole Soul, so as not to suffer the weaker to make any Impression upon it, and thus we become insensible to all the rest which are not in themselves either light or weak?

The furious Passion of *Phædra* for *Hippolytus* in *Racine* does not permit her to feel that strongest Passion in the Fair Sex, the Desire of Beauty. Her Ornaments and her whole Dress are in that Disorder which perhaps neither the Absence
nor

nor Death of her *Theseus* could ever have produced in them.

I comprehend you, replied the Marchioness, notwithstanding your parabolical Method of explaining this Point. The very great Attraction which Bodies feel from the Earth, if I may use the Expression, render them insensible to that of the other Bodies which surround them. Bodies, answered I, attract only in Proportion to the Quantity of Matter they contain. I make no Scruple of using mathematical Terms to you, for to use any other would be an Affront to a Person who has given the Solution of a Problem.

Thus a Ball of Gold, besides many other Advantages, has a greater attractive Power than that of Wood, because it has a greater Weight; and if the first be a hundred times heavier than the last, that is, if it contains a hundred times greater Quantity of Matter, it will have its attractive Power a hundred times stronger.

Now the Attraction of this great Ball upon which we stand is diffused on
all

all Sides, and draws every Thing to it with an immense Force, and by that Means hinders us from perceiving the Effects of that particular Force, which the little Balls by which we are surrounded exercise upon each other.

A Globe of the same Density with the Earth, and of a Foot Diameter, attracts any little Body placed near its Superficies, twenty Million times less than the Earth does. The Attraction of the highest Mountains as that of *Pike Teneriff*, *Ararat*, or even the *Apen-nine*, notwithstanding the pompous Description made of it, is absolutely imperceptible.

But it is not so with the Effects of the Lunar Attraction upon this vast Collection of Waters that some Philosopher made the first Principle of Things, which by the easy Method of Navigation joins the most distant Countries, and transports to us from another World those Balms and Aromatics which season the *European* Entertainments. You seem, replied the Marchioness, to have a very lively

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lively Sense of our Obligations to the Ocean, and the Advantages we receive from it. But has not the Philosopher amidst these Entertainments forgot the Attraction of the Moon? The Ocean, answered I, every Day shews us the Effects of this Attraction, which extends its Empire throughout all Nature. The Ebbing and Flowing of the Sea, a Phænomenon, which, in the most polished Age of Greece, *Alexander* the Great took as a Mark of the Divine Displeasure, and with which the *Romans* in the Golden Age of *Julius Cæsar* were but very little acquainted, is only a Consequence of that Attraction the Moon exercises upon the fluid and yielding Part of our Globe. *Chapelle* in his celebrated Voyage, that Model of polite and agreeable Wit, believed that no one but a Water-God could penetrate into its Cause.

This God relates to him, that when *Neptune* was made Governor of the Sea, the Rivers went to congratulate him. The *Garonne* upon this Occasion retained something of the haughty Temper of his Country, and his Compliments were not
so

so submissive as was necessary in addressing that Power who raises the Tempest by a single Nod, and with an *I will* — silences them to a profound Calm.

The Punishment which this arrogant River received for his Crime, was to be repelled twice a Day back to his Source. All the Rivers which flow twice a Day into the Ocean undergo the same Fate. But why, answered the Marchioness, should the other Rivers who were not guilty of this Gascon Behaviour suffer the same Punishment as the *Garonne*? If it was permitted to make Objections to Superior Powers, I would humbly propose this to *Chapelle's Neptune*.

You may make Objections equally strong, answered I, to all the human Systems that have been made to explain this Phænomenon. Some affirmed the Respiration of this vast Animal the Earth and the Sea to be the Reason of it, others a great Gulf in the Northern Ocean near *Norway*, which emits a vast Quantity of Water and afterwards swallows it up again, a most fatal Circumstance both for the Fishes and
Philosophy

Philosophy which have the Misfortune to be plunged in its Deeps. The ancient *Chinese*, who supposed their little Country of four Leagues Extent, to be the Universe itself, asserted that two great Nations descended from a certain Princess, the one inhabiting the Mountains, and the other the Sea-shore, had frequent Wars with each other, and this was the Reason of the Flux and Reflux according as either of the Combatants was drove back towards the Mountains or the Sea.

Such perhaps was the Infancy of Philosophy among all, even the most sagacious People. The Explication of *DesCartes* which was produced in a later Age of the World is ingenious enough to render it agreeable, but not accurate enough to be true. The same *English* Philosopher who cast an impenetrable Obscurity over Vision, by involving it in his contractile and expansive Forces, has endeavoured to involve this Phenomenon also in the same unintelligible Terms. This gloomy Fancy diffused itself like an universal Contagion
over

over the whole Face of Things, and infected the whole System of Natural Philosophy.

According to his Opinion, the most simple and evident Method of explaining the Tides, is by ascribing their Cause to the contractive Forces of the Earth and Moon, by which the one raises and the other depresses the Water. To these he unites the expansive Force of the Sun, which, tho' always contrary to the contractive, yet upon this Occasion must act in Concert with that of the Moon. These unintelligible Terms, which have not so much as the Fashion to support them, can imply nothing in the Author but a vehement and vain Desire of giving his Name to a new System of Errors. These Philosophers, said she, appear to me the Priests of *Chapelle's* Divinity : Their Explications at once discover both the Temerity and Weakness of their Philosophy. Our's, answered I, takes delight in Difficulties, and comes off in Triumph ; amidst the Thorns we are sure at least to meet with Roses.

That

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That Portion of the Water immediately under the Moon and nearest to her, must be more strongly attracted than the rest which she looks obliquely on, and which is at the greatest Distance from her. The Ocean then must flow together from all Parts, and be heaped into a Mountain of Waters whose Summit will be under the Moon herself.

The Earth itself is a little attracted by the Moon, but that Part of the Water which is directly opposite to the Part under the Moon is least attracted, because it is at the greatest Distance.

This Part then will be as it were forsaken by the Earth which a little follows the Attraction of the Moon, and will there form the Summit of another watery Mountain, and thus there will be two, the one totally opposite to the other.

The Ocean then must swell, and in some measure lengthen itself in that Part where the Moon is, and in the Part opposite to her, and thus from the Figure of an Apple be changed to that
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of a Lemon, whose Extremities will always follow the Moon in her diurnal Course; so that the Water will be at one Time depressed, and at another raised, both in the same Place.

In every Part of the Ocean there will be two Tides, during the Time which the Moon employs in returning to the same Point of the Heavens. When she is at the Meridian the Waters must be raised, and when she sets, depressed; another Elevation when she is at the Meridian of the *Antipodes*, and another Depression when she rises.

All this must unavoidably happen if the whole Earth was covered with deep Waters, and they immediately obeyed the attractive Force of the Moon. But because there is some Time necessary for the accumulating the Waters, and their Course is interrupted by Shores, Straights, Islands, and the like, there are some Irregularities in the Tides.

These Irregularities however are not so great, but twice in every twenty five Hours (which is nearly the Time that the Moon employs in her Return to the Me-

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Meridian) we see the Vessels laden with the Riches of the Universe go up with the Tide along the Silver Waves of the *Thames*, and twice descend with the Reflux to go in Quest of new Treasures. And this Advantage, which in the System of *Chapelle* was inflicted as a Punishment, all the Rivers which flow into the Ocean enjoy.

Have our *Mediterranean* Rivers, said the Marchioness, ever offended the Moon, that they are not suffered to enjoy the same Advantage? Perhaps they have affronted her as the *Garonne* did *Neptune*.

The Straight, answered I, by which the *Mediterranean* has a Communication with the Ocean, is too narrow for so great a Sea, and is disadvantageously situated, (since it looks towards the West) to receive the great Flood of the Ocean that follows the Moon from East to West.

On the other hand, the Tide which is formed in the *Mediterranean* itself is too much interrupted with Islands, Shores and Straights, for the Flux and
Reflux

Reflux to be very considerable. In the *Adriatic*, on the contrary, it is more sensible than in any other Place, because the Sea is very narrow, just as the Motion of a River is most apparent and seems most rapid when confined between the Arches of a Bridge. In our fine City founded by the Gods upon the Ocean, the Vicissitudes of the Flux and Reflux carry the fluctuating Gondolas from one Side to another, while the Gondolier sits at his Ease and singing to the agreeable Light of the Moon, teaches the Sea-nymphs the Flight of *Erminia*, or *Rinaldo's* Love.

The Changes of the Tydes are still less perceptible in the *Baltic-Sea*, the *Mediterranean* of the North; for this Sea bordering upon the frozen Regions of the *Pole*, and very distant from the Course of the Moon, seems more adapted to Ice and Rocks than to Warmth and Attraction.

In the Shores of the southern and oriental Oceans, to *Japan* and *China*, the Tyde is very considerable by reason of the Extent of the Seas; and
in

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in our Ocean its Effects are incredibly prodigious. There are Coasts near *Dunkirk*, where the Sea draws back for the Space of several Miles, and afterwards on a sudden returns and overflows the same Space again, alternately covering and disclosing those Sands so very suspicious to Sailors, not without sometimes disturbing the Ladies in that Country, who venture to walk upon the Margin of the Sea, whose very Shores are faithless and deceitful. These are a Sort of natural Sea Fights, where at some Parts in the Day two Armies may engage on dry Land, and at others, two Fleets, at least such as those of the Ancients were.

In some Rivers the Tide rises to more than fifty Foot high, especially if the Sun and Moon act in Conjunction to render the Flood considerable.

Tho' the Moon may be regarded as Empress of the Ocean, the Sun however has his Share in it. Notwithstanding he is at a greater Distance from the Earth than the Moon is, yet in Return he is so much greater, that it is not pro-

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per he should remain idle, but lend his Part to the Production of the Tides. The rest of the heavenly Bodies have no sensible Influence in this Case, the vast Distance they are separated from us renders them too small.

When the Moon is in her Quadratures the Tydes are less than at any other Times in the Month. The Reason of this is, because the attractive Forces of the Sun and Moon crossing each other, are as contrary as is possible to the Swelling of the Sea in the same Situation.

On the other Hand, when the Moon is new or full, she is in the same direct Line with the Sun in respect to the Earth, their Forces are united, and then the Tides are highest.

It is to be observed however, that the Motion begun in the Waters and retained for some Time within them, must be some Days after the new or full Moon, before it produces the greatest Raising of the Sea. So in Summer, the Heat of Mid-day that remains in the Air, being added to the following

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ing Heat, less intense in itself, is the Reason why we have not so great need of the Assistance of the Fan to supply us with fresh Air at Noon itself, as we have some Hours after.

The greatest of all the Tides happens at the new or full Moon of the Equinoxes; for besides the Conjunction of the solar and lunar Force, the Waters in this Case acquire a greater Agitation; but because the Sun (notwithstanding our freezing) is nearer to the Earth in Winter than in Summer, these great Tides do not happen at the precise Time of the Equinoxes, but a little before the Vernal, and something later than the Autumnal, that is, in the Month of *February* and *October*.

In *Mercury*, *Venus*, and *Mars* the Tides are governed by the Sun alone, tho' they must be almost insensible in *Mars*, because that Planet is at so great a Distance from him. In *Jupiter* and *Saturn* the Distance from the Sun is so very great, that he can have absolutely no Influence over the Tides. They will confound each other accord-

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ing to the Caprice of the Satellites, the great Number of which will render them very irregular.

If we knew the Time of *Saturn's* Rotation as we do that of *Jupiter's*, and were as well acquainted with the Geography of both, and the Quantity of Matter contained in their Moons, as we are with their Distances and Revolutions, we might conjecture the Quantity and Period of their Tides, and send Tables of them to their Pilots. Thus are we again transported by Attraction into Heaven, to vast and remote Worlds where this powerful Quality holds its most conspicuous and shining Seat.

By the Help of this, replied the Marchioness, we can travel thousands of Miles in an Instant, and are well recompensed by innumerable great and shining Truths. A *French* Author, I answered, a zealous Propagator of this System, like us transported by Attraction to these distant Worlds, thinks with great Probability, that the Moons of *Jupiter* and *Saturn* as well as ours had once been Comets, which passing near
enough

enough to these Planets to remain confined within the Sphere of their Attraction, were constrained to revolve round them, and thus degraded from the Rank of Primary to that of Secondary Planets.

Saturn has obtained so advantageous a Situation as to make him the most happy in the Number of his Conquests. For the same Reason he was able to acquire a fine Ring that incompasses his Body, and which was formerly a Comet that unhappily passed too near him.

This *Saturn*, replied the Marchioness, must be very terrible to the Comets that approach a little too close to him. He must be the same to them as the *Cabo tormentoso*, to which Avarice afterwards gave the Name of *Good Hope*, was to the *Portuguese*. It must, I fancy, have been a very agreeable Sight to see *Saturn* at once adorn and enrich himself with a splendid Ring, while the poor Comet was forced to pursue its Journey, spoiled of the Honour of its shining Train.

He robbed it of nothing, answered

I, but what it enjoyed at another's Expence, according to the Supposition of a certain *French* Author, who assures us that the Comet in crossing the Atmosphere of the Sun, had from thence stolen its Tail. But the *Newtonian* Opinion is, that the Tails of Comets are formed and composed of certain Vapours arising from the Comets themselves when they are near the Sun.

Is it not a very great Advantage, replied the Marchioness, to be possessed of a System that supplies even the Imagination with the most pleasing Amusement, by those strange and surprising Events which it renders possible? And all this, answered I, only by the Force that among us makes a Stone fall to the Earth. This Attraction, said she, appears to be the same in the Hand of Nature, as the Subject of a Composition in that of a skilful Musician. Be it never so simple, yet when he undertakes it he will diversify it a thousand Ways, and make it appear every Moment new; in short, he will find enough in

in it to form the most harmonious Concert in the World.

Nature, continued I, wants no other Subject at once to regulate and vary those innumerable and vast planetary Systems, which probably revolve round the fixed Stars, those luminous and attractive Suns that cheer the Night, and which we debase by giving them the Names of our miserable Heroes. But why should these Heroes, said the Marchioness, remain unmoved and fixt? If they have a mutual Attraction, how comes it to pass that they do not approach each other and run all together? You have, perhaps, some other Parable ready which only waited till I should propose a Difficulty. No Madam, answered I, unless you take it for a Parable when I tell you that this would exactly happen, if the Number of those Suns was not infinite. Those which are upon the Superficies of this immense Sphere of Suns would be united to those next them, because they would not have any thing to attract them a contrary Way, and by that Means keep them in their Orbits. And thus these

successively running into those next them, and these last into others, they would be all heaped together. By this Means in a little Time there would be in the whole Universe only one Sun of an enormous Size.

But what is the Number of these Suns? What are the Limits of their Sphere? Is not the Center of it throughout, and the Circumference in no Place? The Difficulty you have moved would be alone sufficient to induce us to multiply the Stars *ad infinitum*, even if we had not a thousand Reasons besides.

I am quite lost, replied the Marchioness, in this Infinity of Suns and planetary Worlds; pray let us return to our own. We are possessed of a System capable of diversifying it to Infinity, if we were so fond of Infinity as to desire it. And a System, answered I, which predicts and gives a Reason for the very smallest Irregularities that can happen. After Attraction and its Laws were established, how sublime a Geometry was requisite to find out what Path the Planets must keep in the Spaces

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ces of Heaven, and how much more sublime still to foresee exactly how much they would deviate from that Path in the Constitution of the present System? The Vastness of the Object renders general Rules difficult, and the Niceness of the Variations renders the Exceptions still more difficult.

The Sun who was esteemed immovable in the Center of the System, and imagined himself exempt from any Irregularity, is found however to be subject to it; for the Attraction between Bodies is always mutual, and every Cause must have a correspondent Effect proportioned to its Activity. As the Planets and Sun reciprocally attract each other, he must be sensible of their Force; so that to speak with the utmost Rigour, he continually changes *his*, as they vary *their* Situation with Respect to him. After all our Speculations then, replied the Marchioness, to prove the Immoveability of the Sun, we are at last reduced to make him move again. Had it not been better, continued she with a certain malicious Smile, to adhere to

the common Opinion without giving ourselves all this Trouble? Do not you act like those Persons who after employing their Reason to divest themselves of popular Prejudices, are afterwards obliged to have Recourse to the same Reason to resume them, if they have an Inclination to live and converse with their fellow Mortals?

Our Case, answered I, is extremely different. The Question then was to make the Sun revolve about the Earth with such a Motion as to run a Million and a Half of Miles in one Day. But at present the Earth herself continues to revolve about the Sun, and he has no other Employment than to approach or recede a little sometimes towards one and sometimes towards another Side of the common Center of the whole System. This Motion is insensible in Astronomy, and is in Fact only a mathematical Subtlety with which I thought myself obliged to make you acquainted. If the Planets were all on one Side, you are sensible that their united Forces must act upon him with the greatest possible Strength, in order to draw him back to themselves

selves and make him recede from the Center of the System: They would not however attract him, considering the Enormity of his Bulk, any more than one of his Diameters. I am very willingly convinced of my Error, said she. The Sun, who notwithstanding his vast Size is subject to the general Force of Gravity, may serve for an Example to great Kings, whom neither the Extent of their Fortune, nor the Superiority of their Station can ever exempt from an Observation of the universal Laws of Humanity.

Our Moon, continued I, is at present subjected by Attraction to the minutest and most exact Calculations of Astronomers. Her very Irregularities, her Caprices are reduced to certain and constant Rules. Comets, those Enemies of Systems who made still greater Resistance to the Power of Numbers than the Moon herself, are at length obliged to revolve about the Sun. And tho' their Orbits are much more oblong than those of the Planets, yet they observe exactly the same Laws.

By

By Observations made upon their Appearances Philosophers have assigned what Orbits the Comets must run in this System, and these in Fact are the Orbits which they really have run, almost with the same Exactness as the other Planets, notwithstanding the imperfect Observations left us by the Ancients concerning Comets, the Moderns have ventured to predict the Return of some of them, in the same Manner as they do Eclipses. And indeed what is there which this System might not authorise? A *Titian* could easily judge of a Picture from a rough Draught.

The Prophecy of that Ancient is now fully accomplished, who even in his Time foresaw that Posterity would calculate the Periods and predict the Returns of these Bodies, these eternal Monuments of the Ignorance and Weakness of human Nature.

It is expected that the Comets which appeared in 1658 will return twenty three Years hence, and I hope we may flatter ourselves we shall observe it together, you still young, and I not very old.

old. You shall be the *Urania* to give a right Direction to my Telescope. What a Vicissitude of Things, replied the Marchioness, is there in this System! I am metamorphosed into a *Urania*, and supposed to be young at a Time when it becomes unpolite to talk about Years, and the Non-Appearance of a Comet rendered more fatal than its Appearance! It will appear too soon, answered I, to put us in Remembrance of our past Time, and our Attraction. In this Case, replied she, we may express ourselves contrary to the common Saying,

'Tis Expectation makes a Blessing dear.

'Tis at present indeed a great Happiness to be an Astronomer. They at least expect nothing in vain, and how great a Pleasure do they owe to this System, which gives them a full Power over every Thing in that Heaven which is the Object of their Projects and Desires?

Nothing, answered I, was a greater Curiosity

Curiosity to Astronomers, or more glorious for the *Newtonian* System, than the Conjunction of *Jupiter* and *Saturn* which happened in the Beginning of the present Age, an Age so fertile in the most surprizing Events. These two great Planets were to approach each other, which the vast Extent of their Orbits, and the Time employed in describing those Orbits, had not very often suffered them to do.

If it could ever be hoped to see the Effects of this mutual Attraction in the Disturbance and Alterations in the Motions of the Planets, it was upon this Occasion when the two most powerful in the whole Solar System approached each other, at a Distance however of three hundred and fifty Million of Miles. This was an Observation in *great*, as decisive for the *Newtonian* celestial System as the Experiments of refracting the coloured Rays with a second Prism, in order to prove whether Colour was a Modification of Light or no, was in *little*. The Curiosity in this Affair was so much the greater, because the *Newtonian*

tonian System was then in its Infancy and Time which gives Strength to Truth, and in which Error vanishes away, had not yet decided any thing to the World in its Favour.

The Disturbance which *Jupiter* the greatest of all the Planets occasioned in the Motions of *Saturn*, and that which this Planet reciprocally exercised upon the Satellites of *Jupiter*, were so considerable that they could not escape the Observations and Testimony of Astronomers, even those who were the least inclined to adopt the System, whom a Difference of Opinion from the Wagers held against it, might easily induce to regard this Phænomenon in a very superficial Manner. And Sir *Isaac Newton* had the Pleasure of extorting from his very Enemies so strong and solemn a Confirmation of his System. What are the Triumphs of the *Cæsars* and *Alexanders* (those miserable Conquerors who overturned two Particles of this Globe) when compared to the philosophical Triumph of him who first discovered the vast Extent of the Universe? Astronomy, said the Marchioness, has

has by this Triumph amply rewarded Sir *Isaac Newton* for defending it so well in the Affair of total Eclipses. This mutual Assistance, this Commerce, if I may use the Expression, of Truth, must certainly be a very great Honour to the Sciences. This Commerce, answered I, was never more evidently seen than in Attraction. We may affirm that every Science with a Sort of Emulation contributes to confirm this Truth, just as the whole World anciently did to the raising the *Roman* Empire.

Tho' I told you that the Effects of Attraction are more remarkable in the Heavens than any where else, yet it is also very evident in all Natural Philosophy, Hydrostatics, Chemistry, and Anatomy itself. Mr. *Muscembrook* (who even in Philosophy presents the Character of a true Republican) confesses with that Freedom that becomes a Member of the *Belgic* State, that for the Space of many Years spent in the greatest Variety of Experiments, he has observed in all Bodies certain Motions and Effects which could not be explained
or

or understood by Means of the external Pressure of any ambient Fluid: But that Nature proclaims aloud a Law infused in Bodies by which they are attracted, without a Dependance upon Impulsion. Chemical Fermentations, the Hardness of Bodies, the round Figure of Drops of Water, and of the Earth itself, the Separation of the Juices in the human Body, the Suction of Water by Spunges, its Ascent in those Tubes which from their extreme Smallness are called *capillary*, and a thousand other Things are incontestable Arguments for this Attraction. I believe that after so many repeated Proofs you will permit me to introduce it triumphantly into Optics, in order to explain the Effects which depend on this mutual Attraction betwixt Light and Bodies. It would be very extraordinary, said she, if I should refuse to admit the mutual Attraction of Light and Bodies, after I have seen the *Sun* and *Saturn* attract each other at so enormous a Distance.

Not to say any thing more of Diffraction, answered I, is not Refraction
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an Effect of this attractive Power? Does it not arise from hence, that the Mediums through which the Light passes are indued with this Force in a greater or less Degree, according to the greater or less Density of the Medium? Otherwise the immense Force of the Earth which attracts every Thing to herself, would render it impossible for any Prism, if it were as big as Pike *Teneriff*, to attract the smallest Ray of Light.

While the Light passes through the same Medium because it is equally attracted on all Sides, it will not decline to any, but move forward according to that Direction it received from the Sun or any other luminous Body: If in its Way it meets with another Medium of a greater Force (such as Glass for Example compared to Air) must it not decline towards this Medium and immerse into it, approaching more or less to a Perpendicular as the Attraction of the new Medium is more or less powerful?

In going out of Glass into Air, the
Light

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Light is again attracted by the Air and the Glass ; but because the Force of the Glass is greater than that of the Air, the Light will remain behind the Surface of the Glass from whence it goes out, or behind that of the Air into which it enters, and which immediately touches the Glass itself.

Thus you see how easily by the Help of Attraction is explained a Phenomenon, which *Des Cartes* could not account for, unless by supposing that Light could with greater Facility pass through dense than rare Mediums ; which is in other Words saying, that what makes the greatest Resistance to all other Bodies, must by some other Privilege of which I am ignorant, make the least Resistance to this. It is surprising to see how all that Experiments have discovered to happen in Refractions, are geometrically deduced from this Explication of the *Newtonian* Philosophy.

To me, replied the Marchioness, who cannot enter into the Sanctuary of the Mathematics, it seems a sufficient Proof
that

that as the attractive Force is greater in Proportion as the Density of the Medium is so, the Refraction must in that Case be proportionably greater.

The *Dutch*, answered I, have found it to be much greater in *Nova Zembla* than here among us. The Air is extremely cold, and consequently dense in this Country, the Habitation of white Bears, and some *Europeans*, the miserable Victims of the Avarice or Curiosity of their Species.

By the Help of this very great Refraction they had the Pleasure of seeing the Sun after his long Absence many Days before the Science of Cosmography had permitted him to appear, and the Density of the Air, which generally oppresses and damps the Spirits, served in this Retreat of Misery and Darkness, to revive their Imagination by an unexpectedly early Light.

We may at present hope for more exact Observations upon the Density of the Air and the Refractions of this Climate, which have never yet been examined by philosophical Eyes. A learned
Com-

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Company is now setting Sail from *France* to the *Botbnic* Gulf, and another to *Peru*, in order by their united Observations to determine if possible the true Figure of the Earth, and animated by the Love of Science, have the Resolution to change the Gardens and the delightful Seats of Pleasure in their own Country for the frozen Rocks and Deserts of *Lapland*.

In *North America* the Colds are incomparably more sharp than in *Europe* at the same Distance from the Pole. There are in those Seas Mountains of Ice of the same Date perhaps as the World, among which are sometimes found Ships at full Sail as motionless as upon dry Land.

Doctor *Halley*, whom the *English* Nation regards with the highest Respect as the Friend and Companion of the great Sir *Isaac Newton*, and whose Thoughts are employed on no Objects that are little or trifling, believes that these Countries were once perhaps nearer the Pole than they at present are, that a Comet by giving a Shock to the Earth
altered

altered their Situation and by this Means set them at a greater Distance. But that notwithstanding this the great Magazine of Ice formed before this terrible Shock still remains, nor has the Heat of following Ages ever been able to melt it. Hence proceed the sharp Colds and a stronger Refraction caused by them.

Certain *English* Sailors who above a Century ago endeavoured without Success, to find in *North America* a Passage to the Southern Sea, were obliged to spend the Winter in an Island very little more North than *London*. Every Thing there was transformed to Ice, the House they had built, the Sea, the Ship, and even themselves.

They were obliged to cut the most spirituous Wine with a Hatchet, and the Refraction was so strong that they observed the rising Moon of an oval Figure extremely long, and the Sun when at the Horizon to be twice as big in Breadth as in Length. The Air was sometimes so very clear in the Depth of that severe Winter, that they discovered

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vered more Stars by two Thirds than are usually seen, and the milky Way appeared evidently to the "naked Eye a Collection of Stars. Thus in these Countries there would have been no Need of a *Democritus* to conjecture it among the Dreams of the ancient Philosophy, nor a *Galileo* to verify it by the Assistance of the Telescope.

From a great Number of Experiments made in *England* it evidently appears, that the refractive Power of the Air increases in Proportion to its Density, which is true likewise in other Mediums which refract the Light, but however with some Exceptions. Air, Water and Glass sensibly observe this Proportion. But oleaginous and sulphureous Liquors, and which consequently are combustible, have a greater Refraction than Liquors of another Nature even if they are more dense. Oyl which is less dense than Water, as appears by its swimming upon it, has however a great Force in refracting the Light.

Alas! interrupted the Marchioness, I am a great Enemy to Exceptions, and

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I have a most mortal Averſion to the *but* in Converſation. Every one who takes it into his Head to rail againſt our Sex before our very Face, will doubtleſs except, with a conſtrained *but*, her who has the Miſfortune to be preſent. Satire ſo agreeable to the Malignity of our Mind, becomes cold with theſe Exceptions, our Self-love is not ſufficiently flattered, and Truth loſes too much when it becomes leſs general.

Exceptions of this Sort, answered I, are properly only new Truths which ariſe from the Diſcovery of many Cauſes, which joined together generally concur to produce a certain Effect. This greater Refraction in a leſs Denſity of Medium ariſes from another particular Correſpondence between theſe Liquors and Light. It acts upon them more than upon any other Sort, by agitating, warming, and inflaming them more eaſily. It is juſt then, on the other Hand, that theſe in Return ſhould act more upon the Light than other Mediums do, by breaking and refracting it in a greater Degree.

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May we not conclude from hence that this Force resides chiefly in the sulphureous Parts of Bodies? For this Reason boiling Water, in which these Parts are more disengaged, has a greater attractive Force than cold Water.

In general, Warmth and Rubbing augment the attractive Force which is in Bodies, or make it appear it in a particular Manner. Amber, all Sorts of pellucid Gems, Glafs, Hair, and many other Things when they are rubbed, discover the Force called *Electrical*, and which is communicated to other Bodies, carried to incredible Distances, and whose Effects are surprizing beyond all Belief.

If a Tube of Glafs be rubbed till it gets hot, it will attract light Bodies as Leaves of Gold or Cotton, and afterwards drive them at a Distance. It will raise a Sort of Tempest in a Heap of little Pieces of burnt Paper by attracting and then tumultuously repelling them from itself. In short, this Force is a Species of magic Wand, that communicates and awakens a

L Power

Power in Bodies, which had before lain dormant and inactive.

A Ball of Ivory fastened to a Cord of nine hundred or a thousand Foot long acquires the same Power of Attraction and Repulsion, if the electrical Tube be applied to the other End of the Cord a thousand Foot distant. You had very great Reason, replied the Marchioness, to call this Tube a Sort of magic Wand, for it really produces incomprehensible Effects. At least, it is a Mystery to me that it should with such Rapidity draw the little Bodies to itself, and afterwards with a Sort of Disdain remove and drive them away.

Observation, answered I, which has hitherto been our Guide and Clue in the intricate Labyrinth of Natural Philosophy, will continue to give us the same Assistance in that little Way we have yet to go. It has conducted us to the Discovery of new Properties in Light and Colours, which have opened a new Scene of Optics to Philosophy. It has conducted us to the Discovery of Attraction in the most secret Retreats
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of Bodies; which is likewise a new and surprizing Quality of Matter, by which all Natural Philosophy is changed and renewed; and now this faithful Guide leads us to *Repulsion*, whose Effects in Nature are no less considerable and surprizing.

Are we not to impute it to this Force, that Flies are able to walk upon the Water without wetting their Legs, and that the Particles, which fly off from Bodies by Means of Heat or Fermentation, are set at so great a Distance from each other as to possess an infinitely greater Space than they did at first?

The Air after being compressed may be dilated to such a Degree as to possess a Space more than eight hundred twenty six thousand times greater than it did when compressed, and this without being heated, which would dilate it still more. That you may understand this Force has no less Influence in Heaven than Earth, the famous Comet of 1682 approached so close to the Sun that it was heated two thousand times more than a red hot Iron. The Vapours arising
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from it, and cast at a Distance from each other by the repulsive Force, adorned it with so formidable a Tail that it took up in Heaven the Length of eighty Million *English* Miles. It would have been very bad for us to have been near, and involved in it; for instead of gaining a Ring or another Moon, we should have been calcined and burnt to Ashes like a little Stone in the Focus of a burning Glass.

Some Persons so taken up with the Phantoms of the uncertain *Future*, as not to see the Fugitive *Present*, expect that one Day some Comet will cause the universal Conflagration of this Globe. Comets have perhaps anciently produced a Deluge, have struck against the Earth and overset every Thing in it, and who knows but one Time or other they may bring a Conflagration upon it, after which laying aside its old Spoils like the Snake, it may again grow young and be renewed, and our great Theatre change both its Scenes and Actors.

The present, replied she, is so various and agreeable as it now stands, that

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I am greatly deceived if it may not divert us as yet a long Time without any Change.

But perhaps it is to these Comets that we are obliged for one of the finest Changes, and what we every Day enjoy. They are perhaps the ingenious Mechanists that have rendered our Theatre capable of being turned round like that of *Curio*, so famous in Antiquity, where the *Roman* People, the Conqueror of the World, the Race of Heroes, and the Portion granted to Mankind by the immortal Gods, sat upon a frail Machine, in which they could not even applaud their public Shews without Danger. We at present perhaps owe to some Comet (without apprehending any calamitous Accident) the Rotation of our Earth, the perpetual and constant Succession of Light and Shadow; in short, the pleasing Variety of Day and Night. One of these perhaps by giving us a Shock has occasioned this Motion in us as well as the other Planets which are discovered to be indued with it.

Before this we had, like the cold Inhabitants of the Pole, six Months Day and six Months Night, but without gaining like them either a strong Refraction or a long Twilight to anticipate and prolong our Day. A little Moon-light would from Time to Time have faintly illuminated that long and melancholy Darkness. What Optics, what Colours could we ever have had for six continued Months, unless the Comet with its Shock had lent us its Assistances. Since every Thing, replied the Marchioness, stands well at present, Heaven guard us for the future from the Proximity of any one of them, from the Shocks, the Conflagrations and the Deluge with which they menace us, and from that repulsive Force that renders them so very formidable. But are not these the Riddles as well as Terrors of Natural Philosophy, that the same Bodies should be both attracted and repelled?

I do not know, answered I after some Pause, whether I ought to introduce you any farther into the Sanctuary of the *Newtonian* Philosophy. There are
in

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in this certain Mysteries still deeper and more sublime than those to which you have already been admitted. You should now invoke those Spirits the first-born Sons of Light, the Guardians of those secret Truths which they imparted to our Philosopher, that they would suffer me to discover to you Things concealed from the Sight of Mortals, and deeply immersed in a gloomy Mist and the most profound Night. You must now entirely divest yourself of those few Remains of Profaneness which may still attend you. Tell me, Madam, what Courage do you feel for Truth? The same, answered she, that a brave Soldier feels to follow his Captain wherever Valour calls. I follow you without Fear wherever Truth leads the Way.

You appear, answered I, to think it a Riddle in Philosophy that the same Bodies should be both attracted and repelled; and indeed there is some Reason for your thinking so. But would not the Riddle be still greater, if I tell you that these two contrary Forces, the

attractive and repulsive, are of the same Nature, and in short it is only the same Force which discovers itself in different Manners and various Circumstances? The Marchioness at this could scarce forbear laughing. What! said she, do you call the attractive and repulsive Force the same Thing? One acts directly contrary to the other, since the first attracts and the last repels. Are these those sublime Mysteries in Natural Philosophy of which you hardly thought me worthy, and which you have introduced with so much Apparatus? Does not all this greatly resemble the Physician in *Moliere*, who affirmed roast and boil'd to be the same Thing?

What! answered I, do you ridicule the most sacred Things in Natural Philosophy, and of whose Use you are yet ignorant? What a Spirit of Prophane-ness still remains in you! But you shall quickly be punished. Remember the Conclusion which you yourself just now deduced from that very Attraction you made so great a Difficulty to admit. Ladies of all Persons have least Reason

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to be surprized that the same Thing should produce contrary Effects. Do not the highest Reserve and an evident Partiality often proceed from the same Principle, and teach Connoisseurs to draw the same Conclusion from them? The Sun hardens and softens according to the different Circumstances in which he exercises his Heat.

This Truth is no less evident in the most noisy Affairs of human Life than in the Phænomena of Gallantry and Natural Philosophy. The same Thirst of leaving an empty Name and Living in the imaginary Breath of Posterity, burnt the Temple at *Ephesus* in *Asia*, and precipitated a *Roman* and his Horse into an open Gulf in the Midst of the Forum at *Rome*. The same Passion made *Curtius* an Hero, and *Erostratus* an Incendiary.

There are certain Things which to the Vulgar, nay even the philosophical Vulgar, may appear as evident Contradictions in the same Man, whom some upon that Account have imagined to be double (as others did the Governor

of the Universe) so then what the one willed the other disapproved, but are not these Contradictions the necessary Consequences of the same Passion and the same Motives?

Thus the very same Cause, by which Bodies are attracted, may in some Circumstances repel them. There are found certain Analogies between these two Forces, which give us great Reason to conclude that they are in reality only the same Force which produces different Effects.

It is generally found that where the attractive Force is weak, the repulsive too is weak, and where the one is strong, the other is strong also. Refraction which depends on one of these two Forces, and Reflection on the other, are both effected where there is a Surface that separates two Bodies of different Density. For while the Rays proceed in the same Medium and do not meet with one of a different Density, they are neither reflected nor refracted.

Those Rays which are most refrangible,

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gible, are likewise more easily reflected than the rest. In Bodies by which the Light is more refracted it is likewise more strongly reflected. And in general, where the attractive Force is greatest, the reflective and repulsive is greatest also. Diamonds, which refract the Light very strongly, give it in Proportion a stronger Reflection. Hence proceed the Vivacity of their Colours and their fine sparkling Lustre.

These Analogies, replied the Marchioness, are very pretty and very good, and so are the Examples by which you introduced them, and very strongly reproach my Rashness. I am heartily penitent for my Fault in laughing when I should have admired, and despising what I ought to have regarded with Veneration. But did not you tell me that Reflection happens when Light meets with the solid Parts of Bodies and is from thence repelled? This Explication seemed very intelligible to me, and perhaps more so than what you at present intimate.

It is *Des Cartes*, Madam, who gave
you

you this Explication, and not I, therefore you may be in some Apprehensions about it. An ingenious Author gives a very useful Piece of Advice, that in Philosophy we should be as diffident of what we imagine ourselves to understand very easily, as of what we do not understand at all.

If Reflection was made when the Light meets with the solid Parts of Bodies (as you so clearly understand it ought to be) do you know what an Inconvenience would from thence arise in Nature, you would no longer have either Toilette or Looking-Glasses?

A Surface, however smooth and polished it may be, is however full of Protuberances and sensible Irregularities discoverable by a Microscope. Imagine all Bodies which you believe the most smooth and polished, to be like Water when it is ruffled by the Wind. The Light must be reflected from all Bodies irregularly as it is from Water thus ruffled, and could never be sent back with that Regularity as is necessary for you to see yourself in

a Looking-Glass. Is not this paying a great Price for your fine Explication? Is it really true, answered she, that it will cost so dear? Perhaps you put me into a greater Terror than the Danger deserves. Is it not possible that these Irregularities in the Surfaces of Glasses, tho' sensible to the Microscope, may yet be insensible to the Light?

You are grown extremely difficult, Madam, answered I. The Protuberances and Cavities in the most smooth and polished Glasses are when compared to a Particle of Light, what the *Alps* of *Pyrenees* would be in respect of a Tennis-Ball. The Irregularities of a Looking-Glass are discoverable by common Microscopes, but there is no Microscope so perfect as to shew the Pores of Diamond, through which the Light however passes very copiously. It would be a terrible Circumstance for us, if the Particles of Light were not almost infinitely small. The Force of Bodies is reckoned from the Quantity of Matter that they contain, which is called the Mass, and from their Velocity; the greater
therefore

therefore their Mass and Velocity, the greater is their Force.

The Particles of Light have an incredible Velocity, for they come from the Sun to the Earth in about eight Minutes, and thus in eight Minutes they run through a Space of eighty one million Miles. Their Velocity then being so extremely great as to exceed more than ten million times that of the swiftest *English* Horses, their Mass must be almost infinitely small, or else a single Particle of Light, instead of animating and reviving all Nature by its Appearance, would produce upon our Earth the most terrible Effects of a Cannon.

The good Effects, answered the Marchioness, of that Diffidence we ought to shew to Men, extend likewise to Philosophers; for by this Means the one gives greater Proofs of what we desire should be true, and the other of what really is so. I will for the future be very careful not to believe you too hastily.

For this time at least, answered I, you cannot accuse yourself of too much

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Credulity. It will never burthen your Conscience that you have not had sufficient Arguments to believe that Reflection is not made by the meeting of Light with the solid Parts of Bodies. For besides the great Inconvenience which would arise if this Supposition were true, Observation informs us, that Light, transmitted through a Piece of Glass, suffers a stronger Reflection at going out of the Glass than it did at entering into it. Now how is it possible that Light should find more solid Parts in the Air than in the Glass itself, to occasion this stronger Reflection?

Besides, if Water or Oyl be placed immediately behind the Glass, the Reflection becomes weaker. Will the Light find fewer solid Parts in Water or Oyl than in Air?

Lastly, if the Air which is behind the Glass be taken away by an Instrument made for that Purpose, the Reflection will be much stronger than it was before the Air was removed. Will you say that Light meets with a greater Number of solid Parts in a Vacuum than in the

the Air? Heaven forbid that I should say it, replied the Marchioness; I will rather make the repulsive Force to be the Cause of Reflection. In these Cases, answered I, it is not the repulsive but the attractive Force. When a Ray goes out of the Glass into Air, it is attracted by the Air and the Glass; hence that Part of it, which was nearest the Glass, returns back as if it had been reflected, if the Air be entirely taken away, this Part being extremely attracted by the Glass, and hardly any Thing by what remains after the Air is removed, it returns back again almost entire.

But if Water or Oyl (which attract the Ray much more strongly than the Air does) be placed behind the Glass, a less Part of the Ray will return back than there did while the Air remained. Lastly, when the Forces of the two Mediums are balanced, as for Instance, when a Liquor be applied to the Glass of pretty near the same Density, or another Piece of Glass, the Ray must pass entire, and there will be no Reflection.

In general, we may affirm that the
attrac-

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attractive Force is the Cause of the Reflection of the Rays when the Light, passes from a dense into a rare Medium; and the repulsive, when it passes from a rare to a dense.

In both Cases, since the attractive and repulsive Force are propagated at some Distance from Bodies, the Light is reflected notwithstanding its Distance from the reflecting Body. Just as when it begins to be refracted, it is somewhat distant from the refracting Medium, in the same Manner as it is from the Extremity of Bodies when passing near them, it is turned out of its direct Path and curved by Diffraction. Hence you see that solid Parts and *Des Cartes's* Explication have less to do with Reflection than ever.

Poor *Des Cartes*, continued she, is attacked in his very last Retrenchments. There is nothing wanting to compleat his Overthrow but for us to assert, that as Light is not reflected from solid Parts, so neither is it transmitted from the Pores of Bodies, and thus he may return back like that momentaneous *Alexander*
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of the North, who after the most rapid and noisy Victories, at length lost the best of his own Dominions.

In order to deny him every Thing and give him Leave to return home as soon as he pleases, we will at least deny that the Quantity or Magnitude of the Pores in Bodies, contributes any Thing to their Transparency. It is proved on the contrary, that if the Pores of a Body, for Instance Paper, be filled with Water or Oyl, it loses its Opacity and becomes transparent; whereas if the Pores in a Body be multiplied, as when Glass is reduced to Powder, it loses its Transparency and becomes opaque.

It is in Homogeneity we are to seek the Cause of Transparency. If there be many Pores in a Body, and these be filled with a Matter different from that of the Body itself, the Light will meet with a thousand Reflections and Refractions in the internal Parts, so and thus it will be utterly extinguished. The Air ceases to be transparent when it is cloudy, tho' it is then lighter than when it is clear,

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clear, and consequently more porous. Its Opacity can arise from no other Cause but that it is at that Time heterogeneous, which makes the Rays that pass through it suffer innumerable Reflections and Refractions, by which Means they are very soon stifled and extinguished. Thus the Froth of Champagne is opaque, tho' much more porous and lighter than the Wine itself.

This seems to furnish us with an Argument to infer, that the Heavens cannot be filled with Matter, however rare it be supposed, even if all contained within the vast Orb of *Saturn*, and tho' its Pores should be as small as you can possibly conceive, might, after being perfectly united so as to leave no empty Space, be grasped in one Hand.

What strange Relation is this you tell me? replied the Marchioness. Is the *Newtonian* Philosophy some golden Fleece which we must not undertake the Conquest of, till we have first passed through a thousand strange Portents, and subdued a thousand Monsters of Imagination.

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Do you believe, answered I, that Gold the precious Substance for which Mankind do and suffer so much, and for which we feel the greatest Thirst when we ought to be most satisfied, Gold I say, and Diamonds themselves, the most shining Work of Nature, notwithstanding their great Weight and Gravity, contain a great Quantity of Matter? It will appear strange when I tell you how very little that Quantity really is when compared to that Vacuum between the Parts, and which to our deluded Eye seems perfectly full.

The solid Parts contained in a Piece of Glass are no more considered with regard to its Extent, than a Grain of Sand to the terraqueous Globe. It is very surprizing how little solid Matter there is in the World, and with how few Materials, if I may use that Expression, it is built. Perhaps if you knew the Truth you would be afraid you walked upon Cotton, and were in Danger of crushing it under your Feet, even if they were as light as those of the swift *Camilla*.

Now

Now if the Matter of the Heavens be imagined unconceivably rare and subtle, yet the Light which, notwithstanding its prodigious Velocity, employs according to the last Calculations six Years in coming from the Stars to us, must be intirely extinguished by that Multiplicity of Reflections and Refractions which it must suffer in that immense Passage; just as a numerous and flourishing Army in a long March must decrease and perish by the Fatigues and Obstacles it meets upon the Road.

I see with Pleasure, said the Marchioness, how the Properties of our Light conduct us to empty Heaven, and after having set the Earth in Motion, to clear its Way. The Diffractions too, answered I, which the Light would suffer from the Particles of this Celestial Matter, would contribute not a little to extinguish it, in the same Manner as they would do in Bodies that are very porous and heterogeneous. It is surprizing that in the Notes which *Perrault* wrote upon *Vitruvius*, he seems, if I remember right, to have had some faint Notion of

of this Truth. Rarefaction, said he, (that is, a Distance of Parts) renders Bodies opaque, because these, which were at first homogeneous when rarefied, become heterogeneous.

It seems much more surprizing, said the Marchioness, that any Person could clearly see and demonstrate that two Things so very opposite as Reflection and Refraction should yet arise from the same Cause. This I must confess will always be a Wonder to me.

The Facility, answered I, and the Obstacles which the Light meets in passing out of one Medium into another, are almost in the same Case. Perhaps an exceedingly subtle Fluid diffused in the Confines of the Mediums extremely quick in its Vibrations, and in which the Light by Percussion excites an undulating and tremulous Motion (as a Stone does in Water, or a Voice in the Air) is the Cause of both the Facility and Obstacles in Question. Thus if the Light happens to be in the Concavity of the Waves of this Fluid, it passes freely through it, but if in
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their Summit, it is drove back again.

Hence come the *Fits of easy Transmission and Refraction*, that is, the same Ray of Light is in one Moment transmitted, and in the next reflected; and because the Vibrations of this fluid are exceedingly rapid, the Rays appear to us both transmitted and reflected at the same Time.

But we are now arrived to the Confines of Nature where our Ideas grow dark and confused; these are the Barriers of Knowledge, beyond which no Force of human Faculties is permitted to proceed, I myself perhaps have run too great a Length.

Sir *Isaac Newton* under the Form of Questions proposed many Things which are probably the Recesses where Nature withdraws to conceal herself from mortal Eyes. The Analogy betwixt Sound and Colour, the strange Metamorphoses of Light into Bodies, and Bodies into Light, the two-fold and surprizing Refractions of Island Chrystal, Rock Chrystal, and that Sort lately discovered in *Brasil*, will always be impenetrable
Enig-

Enigmas to Mankind, since this OEdipus was not able to solve them.

How very different from the modest Doubts of this Legislator of the Wise are the rash Assertions of the Seducers of the Multitude. These however promise those very Men, whom they have always deceived with the same Flatteries, to open the Temple of Truth so often tried in vain, in the most expeditious and easy Manner by the Help of certain new Principles; just as others with certain new Systems of their own spread artful Nets for human Avarice, and promise at once to enrich a Nation which they have always impoverished by the very same Schemes. The Pleasing and vain Delusion of Hope leads some in Haste to the *Bank*, others to the *Academy*. The Beginning of an Affair is generally agreeable to our flattering Expectations. The Wind is commonly favourable to the Ship just loosed from the Port, and two bright Eyes give an agreeable Invitation at their first Appearance. The Bank by converting Hopes at first into Gold pre-

serves

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serves and increases its Reputation, and Philosophy by judicious Prefaces maintains its Honour, more successful in banishing old Errors, than substituting new Truths in their Place. Thus they who by a prudent Diffidence soon extricated themselves from the Snare, either brought back a reputable Increase of their Fortune, or were rationally delivered from their past Prejudices. But there are very few so wise as not to lose the present in forming Projects for the future, or not to make the Happiness of to day, a Step to the Misery of to-morrow. The Cheat at Length is discovered, and the first are left with their Scrutoirs, full of Notes worth nothing, while the last have their Heads embarrassed with Notions of Pressure, Rotations, Globules, and Vortices, the false Coin of Philosophy. Sir Isaac Newton, guided by a slow yet sure Experience, promises no more than what Experience is able to perform. Where that leaves him he stops, by its Assistance he distinguishes Truth from Falshood, Evidence from Probability, and in the Extent of his

own, discovers the Limits of the human Understanding.

Are not the Rays of Light (says Sir *Isaac Newton*) very small Bodies of different Sizes, the least of which make Violet, the weakest and darkest of all the Colours, and more easily diverted by the attractive Force of the *Prism* from the right Path? And the rest, as they are bigger and bigger, make the stronger and more lucid Colours, Blue, Green, Yellow and Red, and are more difficultly refracted, in Proportion to the greater Strength of the Colours, and the larger Size of the Bodies that compose them?

It is certain that the Rays of Light differ from each other in Colour, Refrangibility, and the Force with which they strike our Senses. Scarlet dazzles the Sight, the Azure of Heaven languidly moves it, and the Verdure of a Meadow strikes it with a very pleasing Sensation.

Only one of these Differences, said the Marchioness, had been sufficient to make an ordinary Philosopher put an absolute Difference in the Size of the Particles of Light,

Light, whereas two or three are hardly enough to supply ours with a Conjecture. In the vast and unlimited Perspective of Nature (answered I) there are Objects that we are for ever condemned to see languid and confused, without hoping that any Telescope can make them appear either less distant or more distinct. The Moderation of our Philosopher, in never affirming any Thing to be true which was not demonstrated by Observation, may serve for an Example to the most rash Asserters. Who could have more Reason to think himself capable of ascending Heaven, or bringing the Secrets of Nature in Triumph from thence, than Sir Isaac Newton, who, poised upon the Wings of Geometry, could take his Flight through immense Spaces, till then impenetrable to human Curiosity?

What a strange Condition, replied the Marchioness, is ours! We know what Size in a Particle at a great Distance from our Sight is necessary to reflect a certain Colour, but what is this Colour itself which we have always immediately

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before our Eyes? Hardly can we form any Idea of it by a feeble Conjecture : In one Case we have the Sight of a Lynx, in the other we are absolutely blind. There our Senses are refined beyond what we could have expected ; here they seem to abandon us all at once.

There are some Persons, answered I, who have believed that the many Difficulties which attend our little Degree of Knowledge, the great Number of Systems, the various Emblems of human Ignorance, and that continual tantalizing which Philosophers suffer in their Searches after Truth, proceed from no other Cause than our want of a sixth natural Sense which might reveal a great Part of what is at present hid from us, and escapes perhaps those five Senses given us by Nature to lay hold on external Objects, and bring them to the Mind.

As there are certain Animals among us, who, by virtue of Senses, of which we perhaps have no Knowledge, foresee the Change of the Seasons, and approach of the Morning, and, without having

read

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read *Dioscorides* or any other Botanist, can amidst a thousand others distinguish that salutary Herb that cures their Hurts, who knows but in some other System, (in the World of *Jupiter* perhaps,) there may be Animals which, more sharp-sighted than our Philosophers, may discover the Size of those Particles that compose the Variety of Colours, and in what manner, without the Assistance of Ropes or Pullies, they may attract *Saturn* at a Distance of more than three hundred and fifty Millions of Miles?

But in return, as in that Planet, which is not depopulated by the Race of War, the Inhabitants have no Idea of the Pleasures of Love, so, according to the agreeable Historian of these Worlds, every Thing is diversified, and put in a just Balance; those People who are thoroughly acquainted with the Nature of Colours, may perhaps want the Sense proper to give them a Perception of the most agreeable Harmony of those Colours upon the Cheeks of their *Cbloes*, and tho' perfectly skilled in the Attractions of the Planets, are perhaps

blind

in sense

insensible to the more pleasing Attractions of Beauty, which are preferable to any Speculation whatever.

But however it be with regard to our present Speculation, the most vain perhaps of all others, it is not for our Advantage to seek Occasions to put us in Mind of our Defects, nor be so ingenious in tormenting ourselves. We shall not be destitute of either Knowledge or Pleasure, if we make a good Use of the Senses fallen to our Lot. Though you know nothing wherein consists the Nature of Light and Colours but by Conjecture, there will not perhaps be wanting some Persons to affirm you know much more of it than is proper for a Lady. The Fault will be thrown entirely upon Me, who upon those few Verses which gave Occasion to our Subject, have made you a Comment, long enough for a Poem upon the *Newtonian* Philosophy. It will be well for it, if you dissemble your Knowledge with those Persons who ridicule what they ought to learn, and if to the Science of Natural Philosophy you join that of the World.

What,

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What, cried the Marchioness, am I so learned that I ought to study to be ignorant? May I venture seriously to call myself a *Newtonian*? You have already renounced your philosophical Errors, answered I. The Light of *Newtonianism* has dissipated the *Cartesian* Phantoms which deluded your Sight. You are now really a *Newtonian*, and it is no small Advantage to Truth that you are so. I will some time give a History of the fine Conquest I have acquired for Her, and I am certain if I could give a just Description of my fair Disciple, my Book would never want Readers, nor true Philosophy a numerous Train of Profelytes. You shall be the *Venus* that must lend the agreeable Cestus to this austere *Juno*, and give her those attractive Charms that will render her engaging and amiable to Mankind.

F I N I S.



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When I first saw the manuscript I was
pleased that I ought to study to be igno-
rant of May I venture to say to call
it a Manuscript? You have al-
ready arranged your philosophical
matters and I The Light of
Nature has directed the Course
of Philosophy which debased your
Sight. You are now really a Mathematician
and it is no small Advantage to I think
that you are so. I will come time gives
I think of the Court I have ac-
quired for myself I am certain I I
could give a full Description of my fair
Principle, my Book would never want
Readers, nor true Philosophy a num-
ber of Fools. You shall be
the first to read and the agreeable
Cousin to this sister Yams and give
her those attractive Charms that will
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Mankind.

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